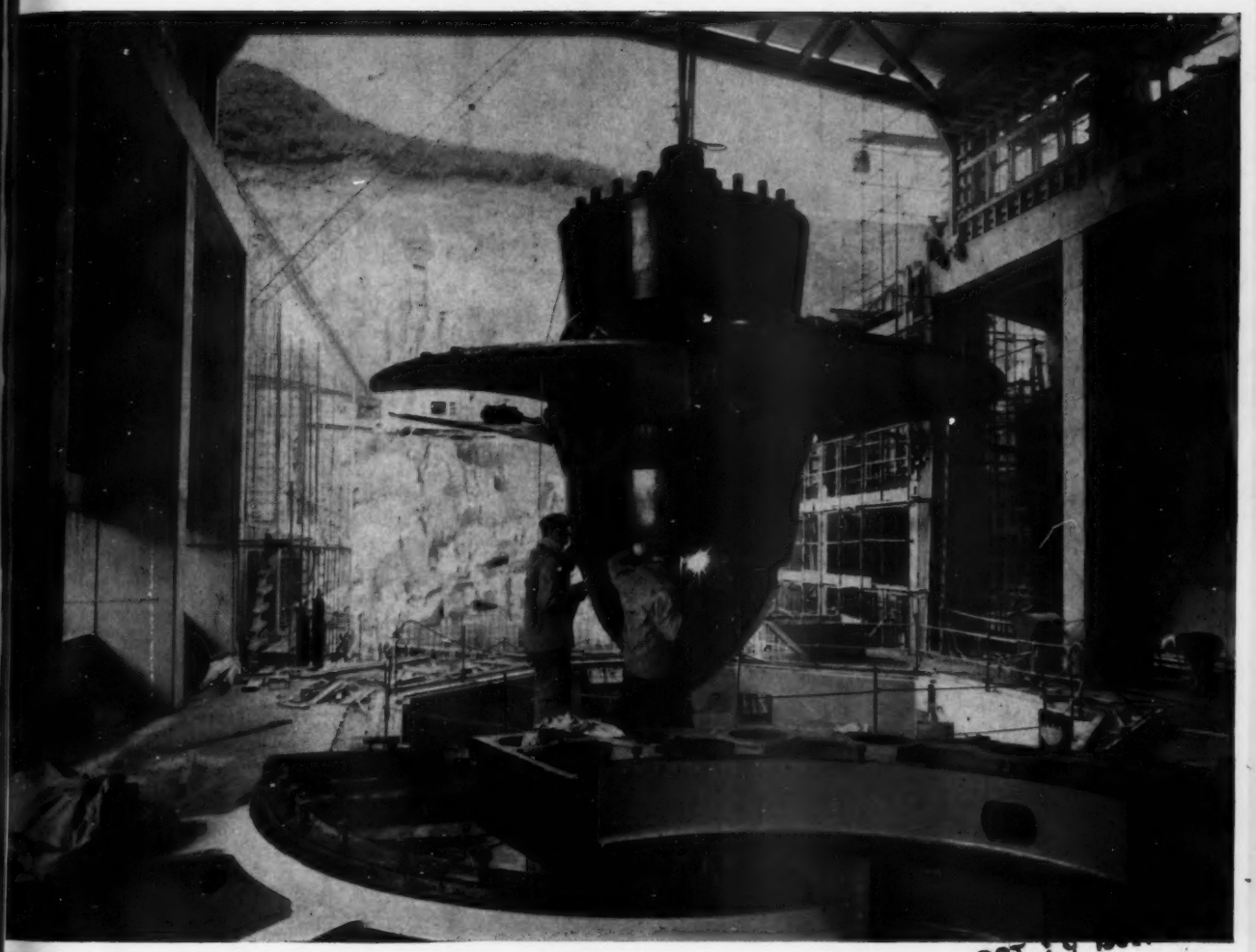
Water Power
AN INTERNATIONAL DEVELOPMENT OF HYDRO-ELECTRIC POWER



OCT 19

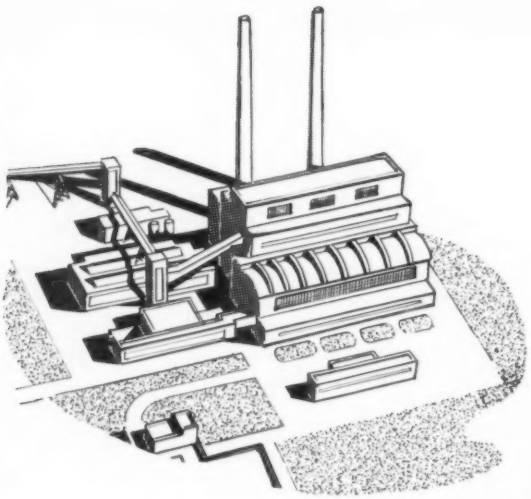
Making final preparations to
a Kaplan runner
before placing in position.

TEXAS ENGINEERS LIBRARY
COLLEGE STATION, TEXAS

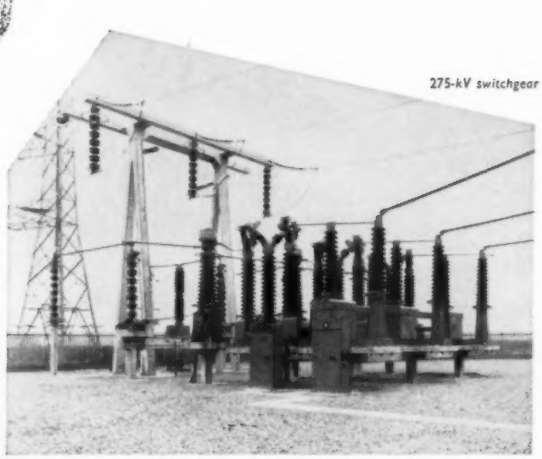
Boving WATER TURBINES

power the WAIPAPA N.Z. hydro-electric station

BOVING & CO LIMITED VILLIERS HOUSE 41-47 STRAND LONDON W.C.2



Blyth A
GENERATING STATION



275-kV switchgear

Main control-room

3·3-kV switchgear

Reyrolle supplied the 275-kV air-blast switchgear, 66-kV small-oil-volume switchgear, 3·3-kV air-break auxilliaries switchgear, and 415-volt distribution gear together with associated control-equipment.

Consulting Engineers:
Messrs. Merz and McLellan

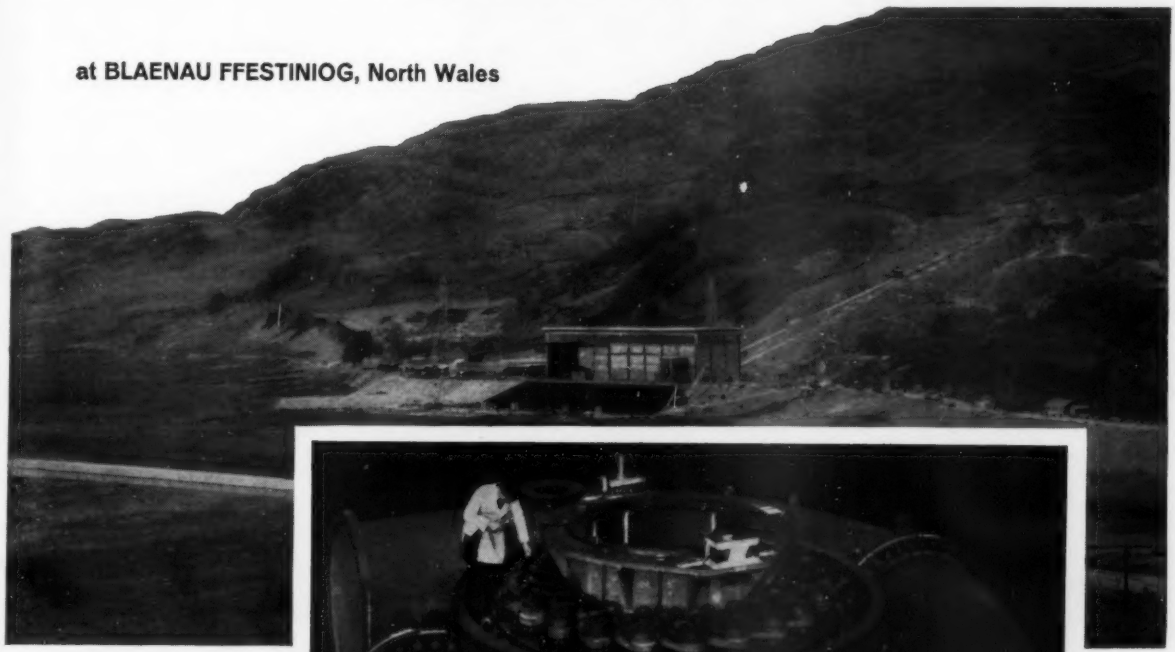
Photographs by courtesy of C.E.G.B., North Eastern Division

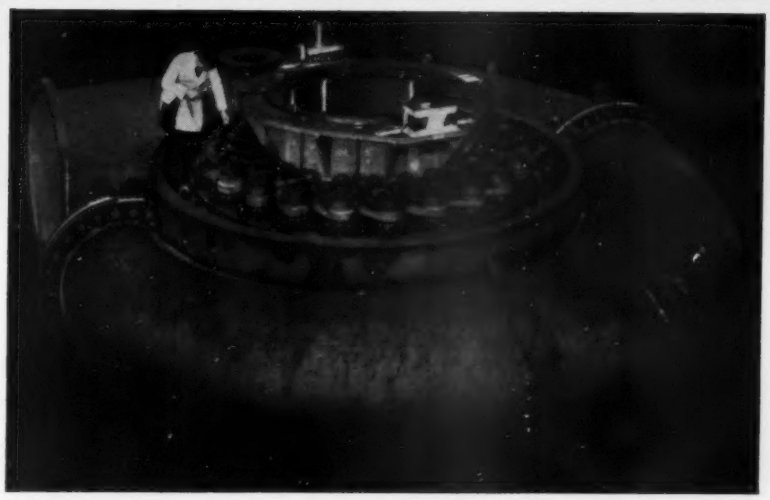
Reyrolle

A. REYROLLE & COMPANY LIMITED - HEBBURN - COUNTY DURHAM - ENGLAND

Britain's first major pumped storage scheme

at BLAENAU FFESTINIOG, North Wales





Consulting Engineers: Freeman, Fox & Partners and Kennedy & Donkin.

'ENGLISH ELECTRIC' is supplying the major part of the plant now being installed in the Central Electricity Generating Board's 300 MW pumped storage scheme at Blaenau Ffestiniog in North Wales.

'ENGLISH ELECTRIC'

hydro-electric equipment

The hydraulic power driving the four 75 MW generators will be provided by four 105,000 h.p. 'ENGLISH ELECTRIC' reaction turbines.

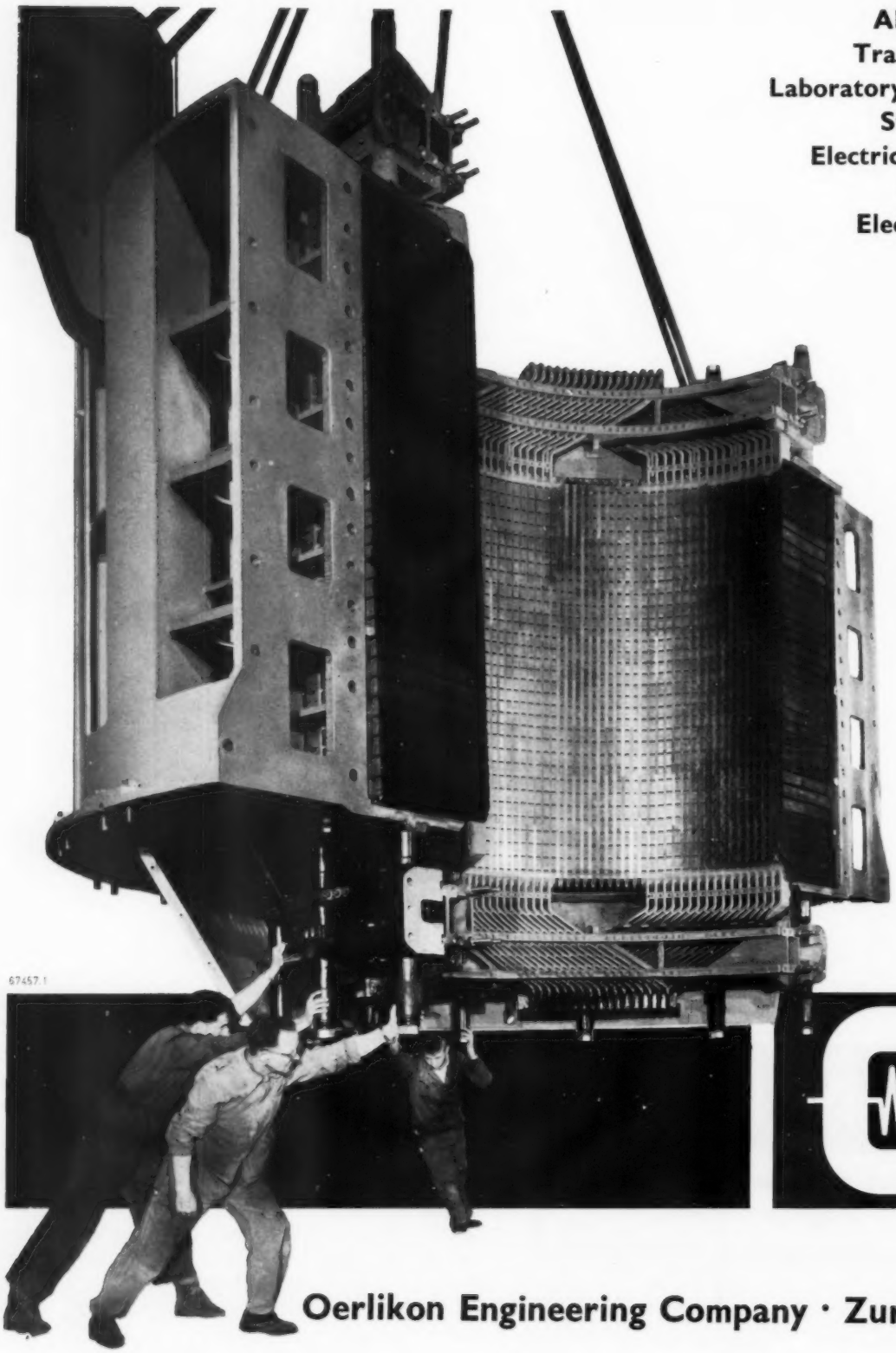
'ENGLISH ELECTRIC' is also participating with SULZER BROS. in the manufacture of four 93,600 h.p. two-stage, double-entry pumps capable of raising 745 cu. secs. against a head of 1,000 ft. The flow of water between the upper reservoir and the power station will be controlled by eight 'ENGLISH ELECTRIC' 'Straight-Flow' valves.

The complete control equipment, switchgear and distribution boards within the power station are also of 'ENGLISH ELECTRIC' design and manufacture.

HYDRO-ELECTRIC DIVISION, DUNNINGS BRIDGE ROAD, NETHERTON, BOOTLE, 10

The English Electric Company Limited, English Electric House, Strand, London, W.C.2.

HE.41



Alternators
Transformers
Laboratory Magnets
Switchgear
Electric Traction
Rectifiers
Electrolyzers

Oerlikon Engineering Company · Zurich 50

+GF+

The highest head in the world

At the Reisseck Power Station in Austria three units work under this fantastic head. All of them are equipped with Pelton runners in 13% Chromium Steel cast at George Fischer's steel foundry and delivered to Charmilles Engineering Works Limited, Geneva.

The successful production of intricate steel castings, such as the Reisseck impulse runner shown here, is the result of our extensive research, wide experience and technical skill in steel founding.

George Fischer Limited
Schaffhausen, Switzerland

Telegrams: Geofischer
Teleprinter: 5 29 15 geofischer schf

the steel foundry for water turbine runners

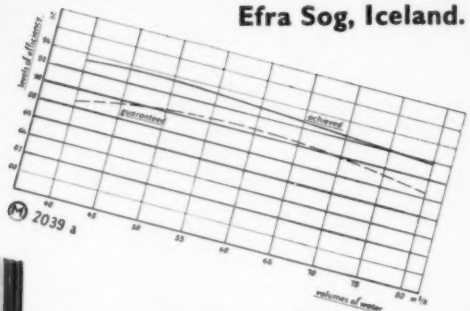
Turbines

built by

Maschinenfabrik B. MAIER K.G. of BRACKWEDE Germany

have already been exported to nearly all the countries of the world, and also, for instance, for the

Steingrimsstöd Installation at the Efra Sog, Iceland.



The illustrations show the installation equipped with 2 Kaplan turbines of approx. 20,000 PS. each.

Our manufacturing programme comprises

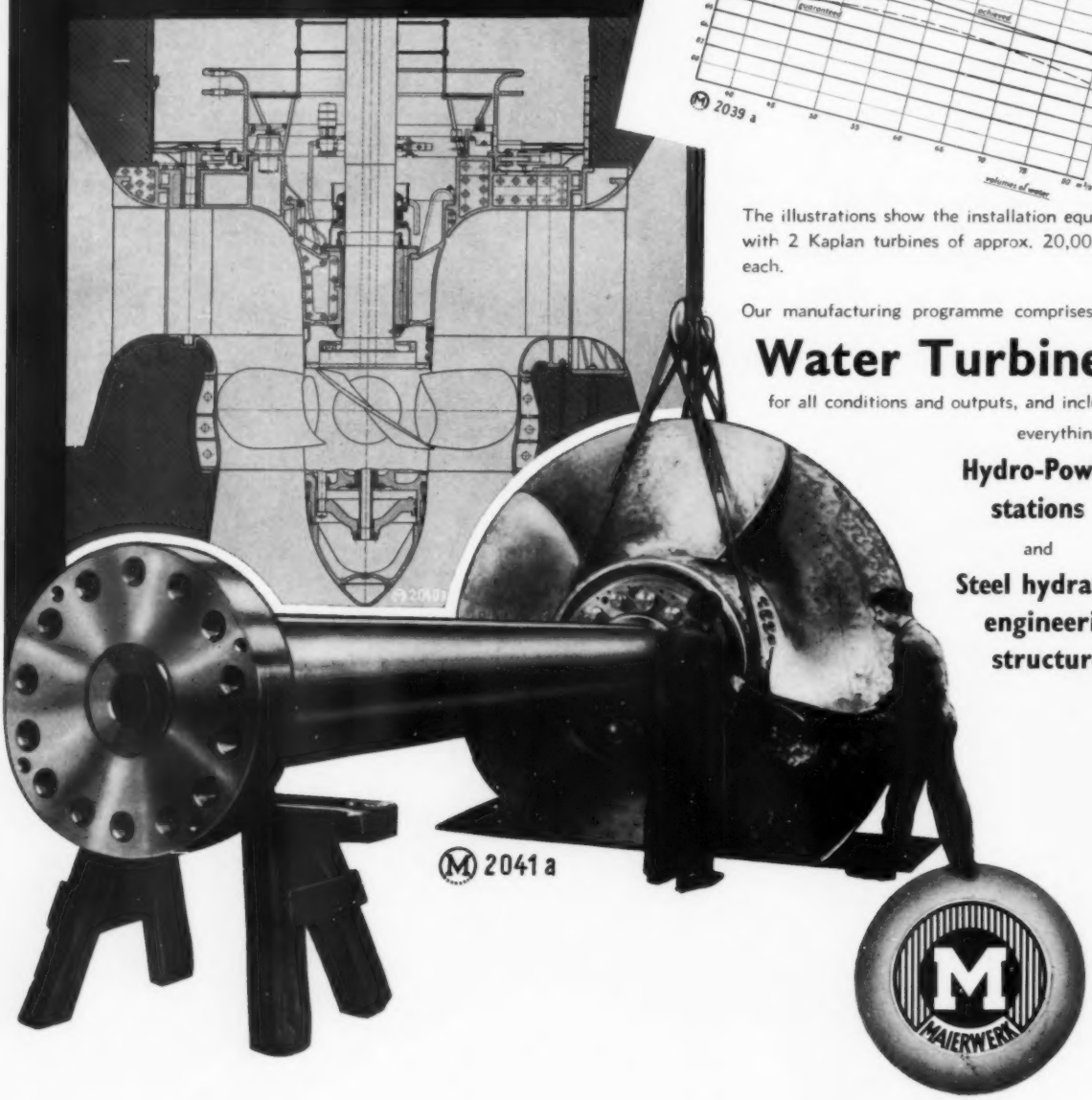
Water Turbines

for all conditions and outputs, and including everything for

Hydro-Power stations

and

Steel hydraulic engineering structures



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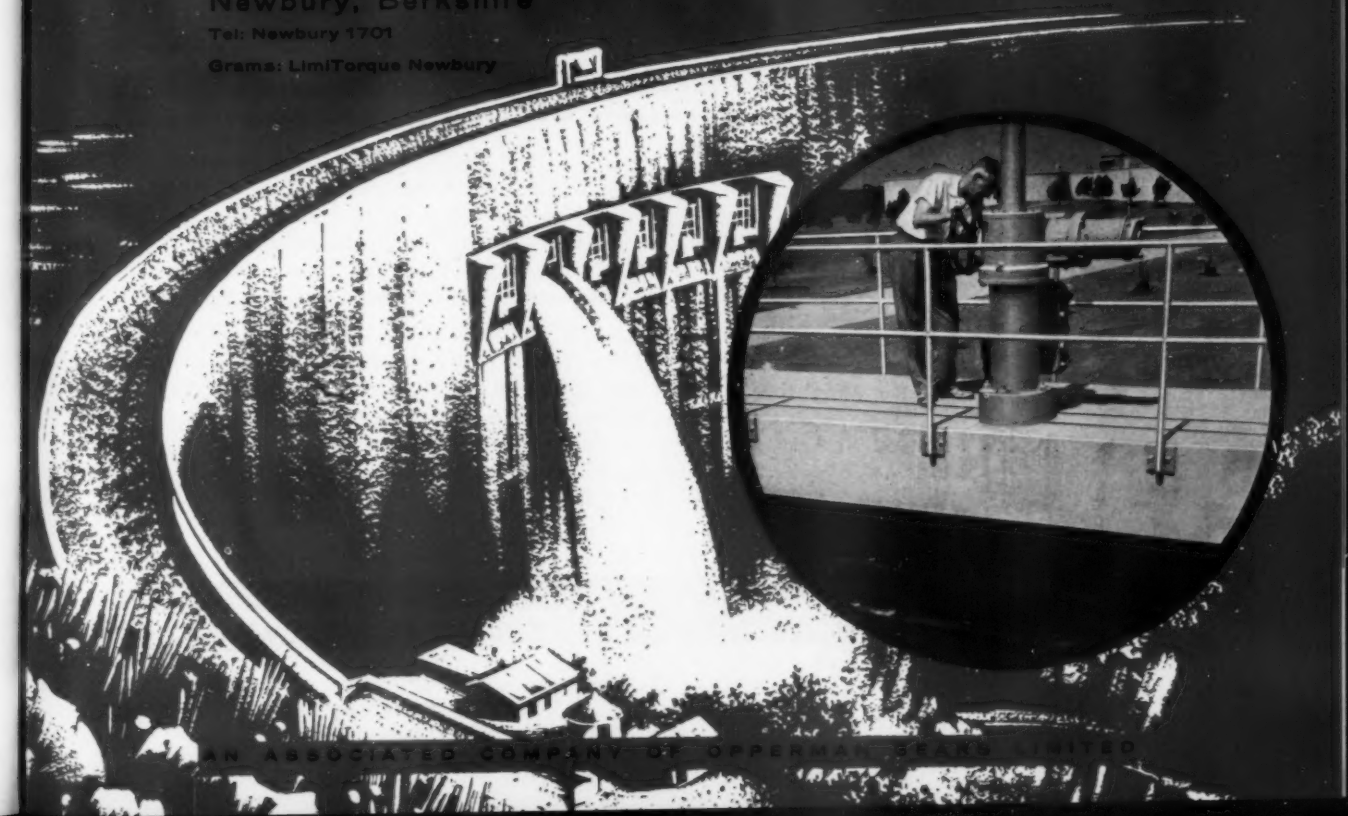
push-button valve control saves time and money

In the hydro-electric industry or wherever large quantities of water have to be controlled, LimiTorque means economy. LimiTorque is the actuator with *fingertip control*. Once it's installed, one man does the work of many— simply, efficiently, with complete dependability. Highly sensitive, and automatic, it can be operated electrically, pneumatically or hydraulically and is easily adapted for use on existing manually operated valves.

LIMITORQUE VALVE CONTROLS LTD
Newbury, Berkshire
Tel: Newbury 1701
Grams: LimiTorque Newbury



AN ASSOCIATED COMPANY OF OPPERMAN BEARD LIMITED

HITACHI

Another Big Hydraulic Turbine and Generator by Hitachi

Hitachi has recently completed two 137,500 kW/125,000 kVA hydraulic turbines and generators for the Miboro Power Station in Central Japan. The turbine is of the vertical-shaft Francis type, and specified for a speed of 225 r.p.m., a maximum effective head of 200m and 76.6 cu.m/sec. water flow, making it one of the largest units of its kind in the world. Its runner has a maximum diameter of 3.7m and the main shaft a diameter of 95cm. The spiral casing, which was constructed in 13 sections to facilitate transportation to the site, has an inlet diameter of 3.35m and an outer diameter of 11.2m.

The generator presents a high-torsoed appearance, having been so designed in consideration of the comparatively high speed. Since the generator was designed for a rated voltage of 16,500 volts and. in this respect, represents the first such attempt in Japan, particular care was taken in the corona-shielding and impulse resistance of the stator winding. The generator is rated at 60 cycles, 225 r.p.m. and 0.9 power factor, but is also capable of operating at 50 cycles, 187.5 r.p.m. and 1.0 power factor.

Hitachi, Ltd.
Tokyo Japan
Cable Address: "HITACHY" TOKYO

It's an old Swedish custom

A foreign visitor to one of the big Swedish shipyards once asked, not altogether innocently: "Do you dust the steel plates every morning?" At Svenska Metallverken you won't see us dusting steel plates, because we don't have any (although quite a lot of our aluminium does go into ships). But you *will* see the same general tidiness that impressed the visitor to the shipyard. In non-ferrous metal manufacturing it is highly important to prevent impurities from entering the product — which is one of the reasons why we install automatic machinery, and why we insist on clean floors and clean machines. The wage agreement we have with our workers does, in fact, include a stipulation that they shall spend the last *paid* hour of the week cleaning their machines. It pays all around.

POWER LINE BUILDERS BENEFIT TOO

Most of the machinery at Svenska Metallverken's Feral Cable department has been designed specifically for the metals in question — in this case aluminium. Here automatic devices help production and offset human failings. Coils of wire rod are welded together before drawing. Large wirebars mean longer rod coils and fewer welds — and even before being coiled, an electronic device has detected any defects in the rod. Then again, there is an automatic device for stopping the machines as soon as a predetermined length of wire has been spooled onto the reels of the standing machines — where it finally becomes Feral Cable, reliable Swedish ACSR.

Push-button operated continuous rod-mill at Svenska Metallverken's Feral Cable department.

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EXPORT DIVISION · VÄSTERÅS · SWEDEN

SWEDEN

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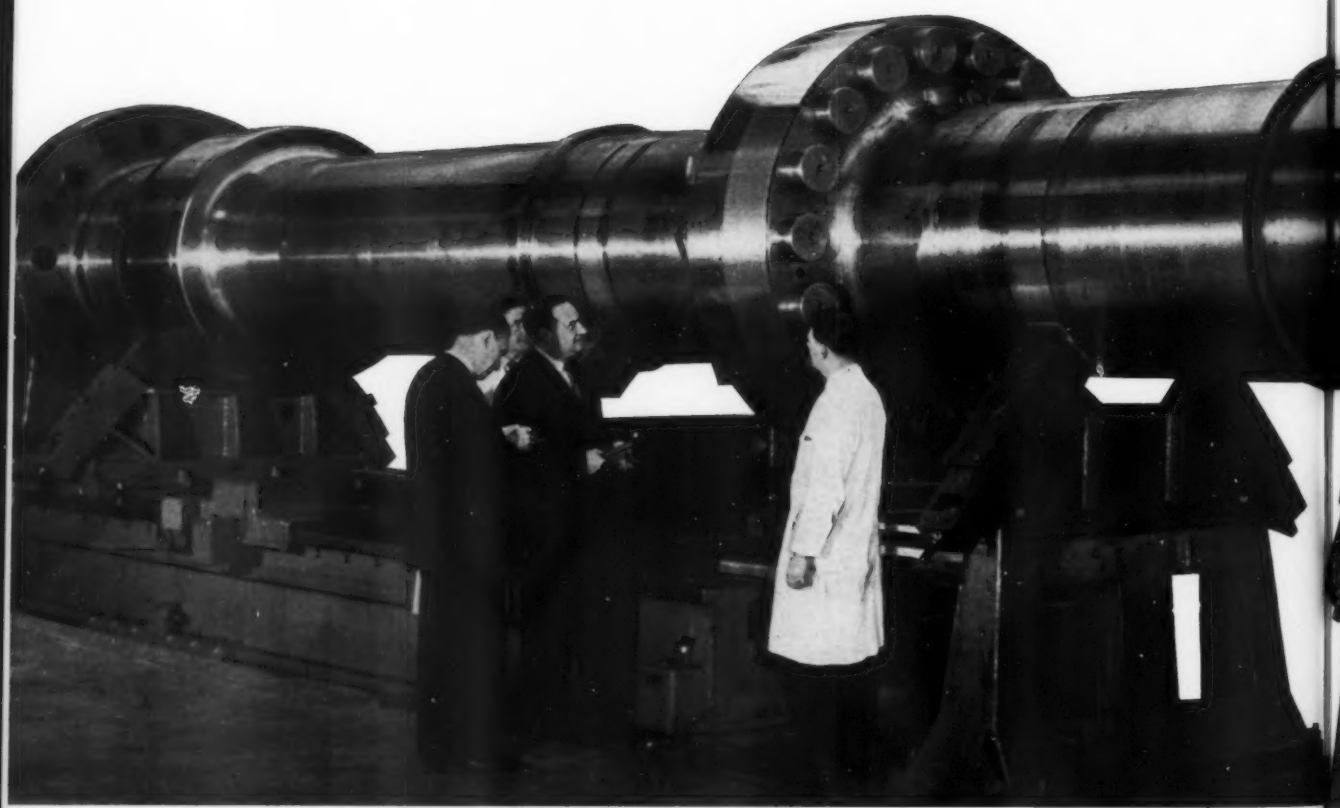

ENGLISH STEEL FORGE AND ENGINEERING C

ne world's Hydro-Electric Power Stations

Canada
Canada
Wales
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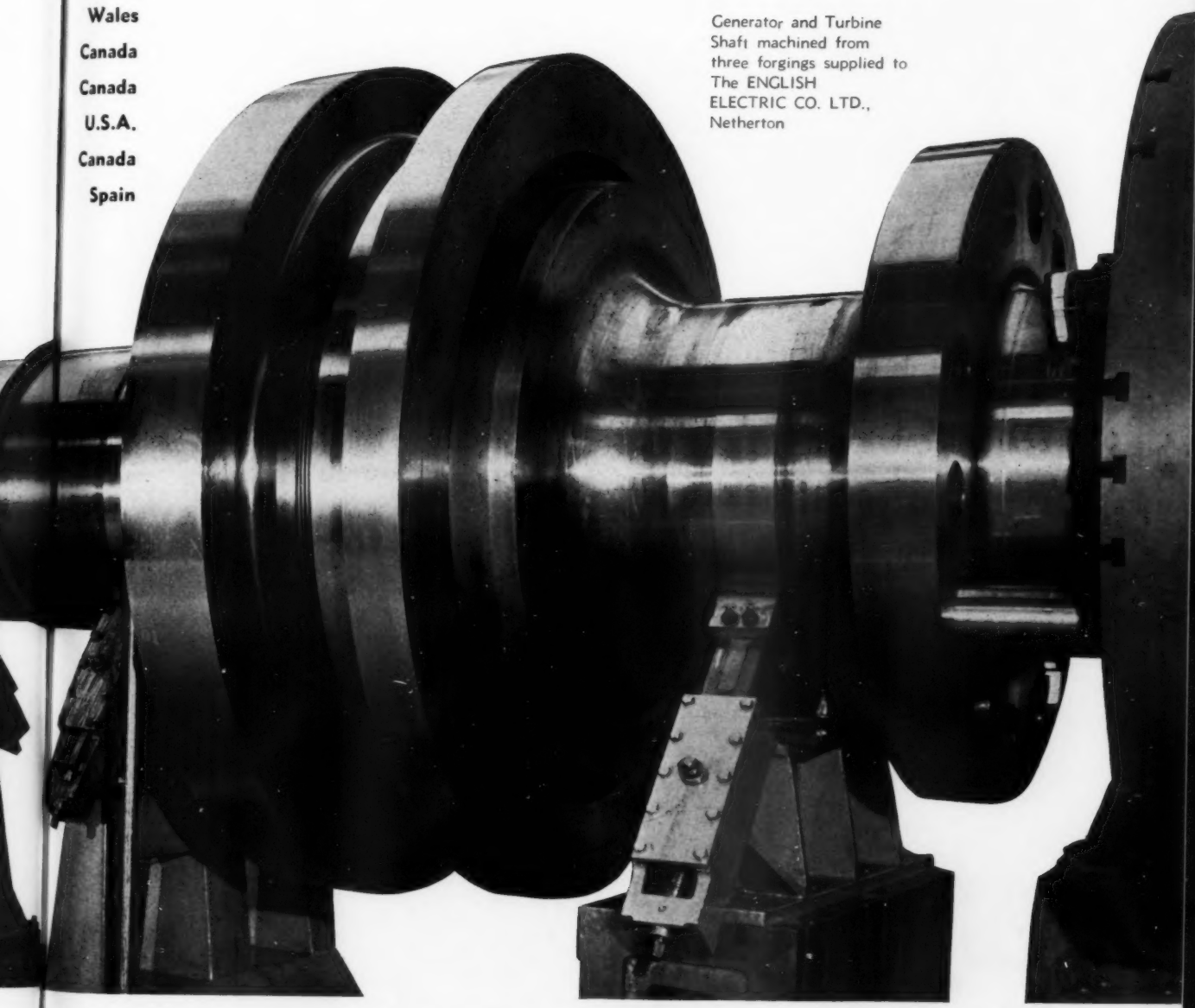
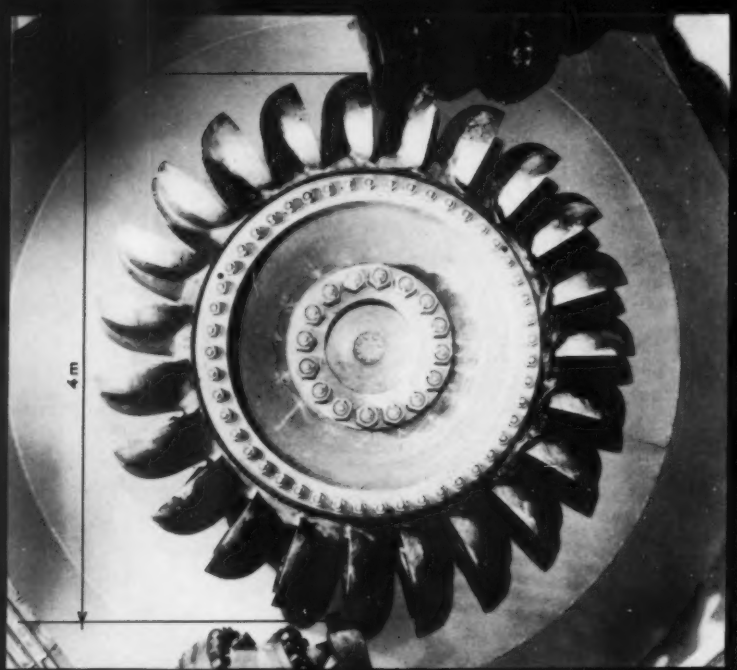
Generator and Turbine Shaft machined from three forgings supplied to The ENGLISH ELECTRIC CO. LTD., Netherton



NG CORPORATION LIMITED · SHEFFIELD

Roselend - La Bathie

500 000 kW
from twelve 41750 kW jets
under a 1126 m head



The Roselend plant near Albertville in the French Alps is situated at a height of 1 550 metres above sea level and provides a reserve of some 200 million cubic metres of water for the 500 000 kW power station at La Bathie.

This output is supplied by six 83 500 kW single-runner twin-jet vertical Pelton turbines, each of which is coupled to its own 88 000 kVA alternator running at 428 r.p.m.

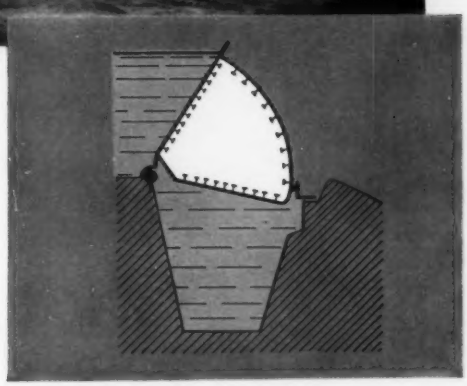
The jets discharge from the individual nozzles under a head of 1126 metres at a speed of 550 kilometres per hour, thus each giving an output of 41 750 kW.
All six of these turbines are **NEYRPIC** - built.

NEYRPIC
Avenue de Beauvert
BP 52 - Grenoble - France
Tel 44-55-30

1033/59

Liapootah Drum Gate in the River Nive, Tasmania.

Gate of 36.6 m clear width and 6.1 m retaining height, acting as a spillway gate of a dam.



Section of a drum gate

M·A·N

HYDRAULIC STRUCTURES

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GUSTAVSBURG/HESSEN (GERMANY) REPRESENTATIVES IN ALL COUNTRIES

WE DESIGN AND CONSTRUCT GATES

**of all systems
for river and
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lock gates,
regulating gates with
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Mooser-Dam of
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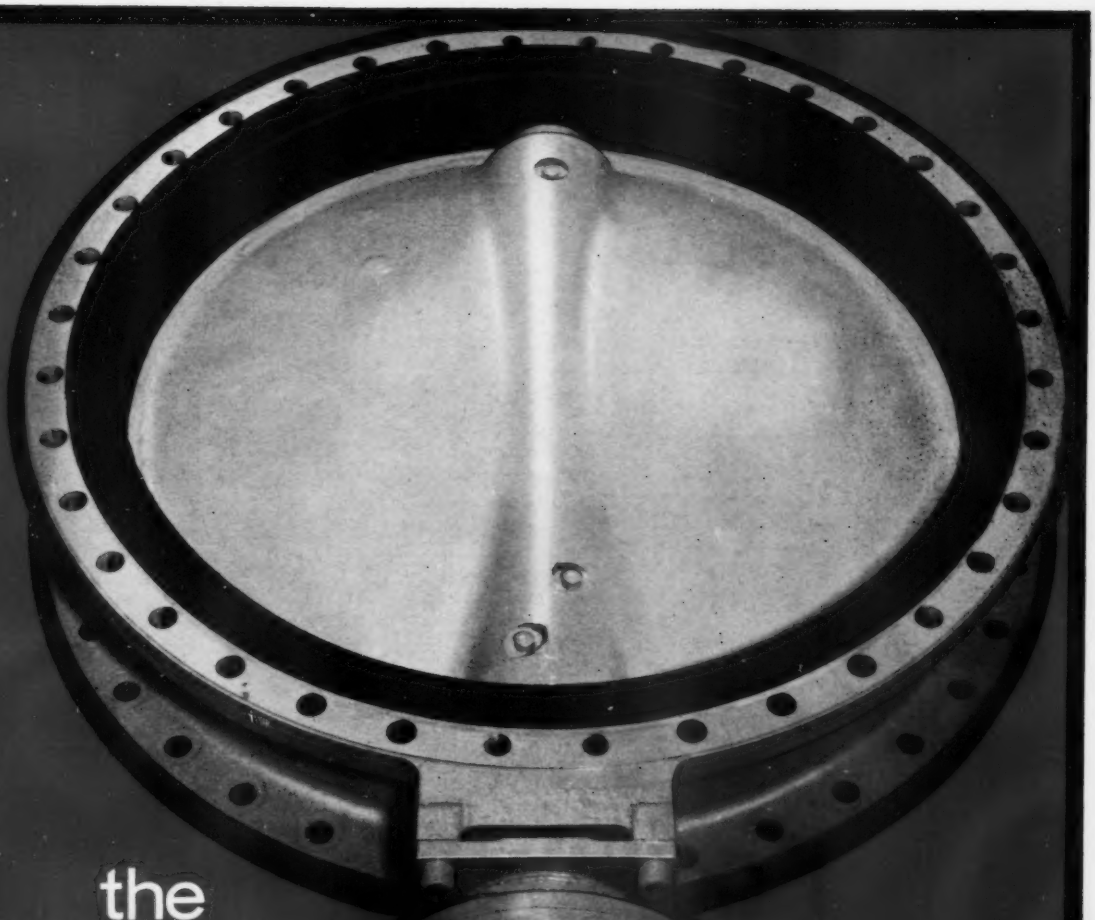
HEAD OFFICE: WIEN V, MARGARETENSTRASSE 70 AUSTRIA



the bigger the better

The Valve illustrated, 42" diameter, is one of a large order supplied to the Greek Water Board.

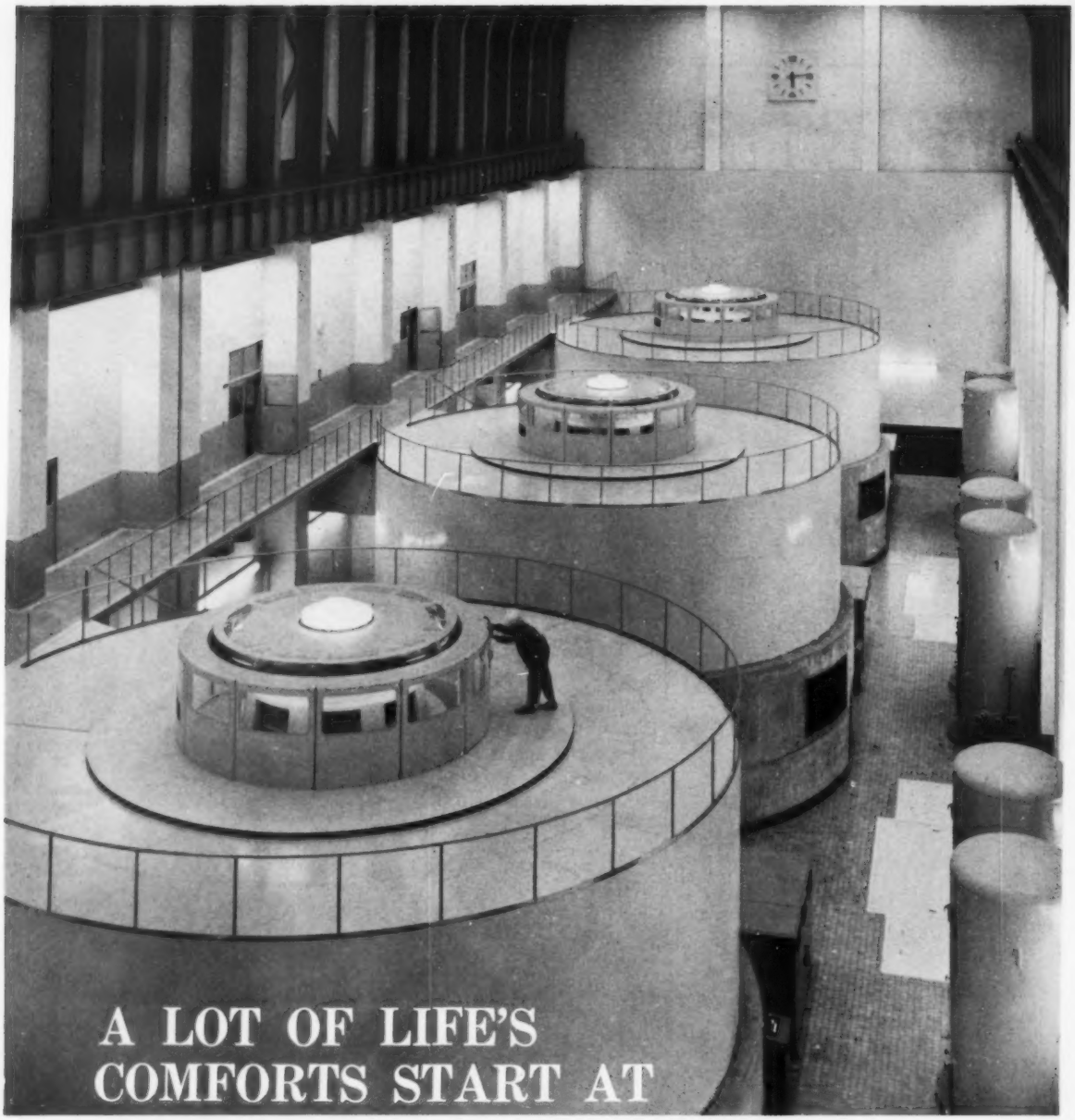
In the 2" bore size, the face to face dimension of a Cockburn-Rockwell Butterfly Valve is 1¾". With a 17½" bore, the valve is 4" face to face. In the 35½" size, the economy in space is even more marked—only 8½" of the pipe run is occupied by the valve. Cockburn-Rockwell Butterfly Valves are the most compact form of pipeline control, and this feature becomes more and more appreciable as the size increases. Valves are currently being manufactured with Bores up to 60" Diameter.

COCKBURN-ROCKWELL BUTTERFLY VALVES

COCKBURNS LTD
Gardonald Glasgow SW1

CWR Certain Cockburn-Rockwell Butterfly Valves including designs with spool liners, are manufactured to a common standard in Britain, United States, France, Holland & South America. Service and interchangeable spare parts for the CWR range are available in all these countries. Full information on request.

105,000 kVA Water-Wheel Generators



A LOT OF LIFE'S COMFORTS START AT

MITSUBISHI ELECTRIC

When you think of giant generators, you rarely think of their vital part in making this world a more comfortable place to live in. Yet Mitsubishi Electric's great generators and transformers, plus many large and small home appliances all do just that..... every day in countless ways. Backed by a long history of outstanding achievements, distinguished by the famous Mitsubishi Brand. Do think about it the next time you see the THREE DIAMONDS on an electric appliance.

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ELECTRICAL PORCELAIN ENGINEERING

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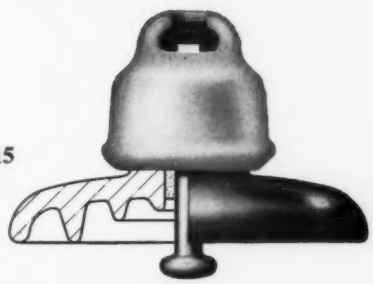
Backed by a century and a half of ceramic manufacture, a first class research laboratory, a modern factory, a highly trained technical staff and the latest test equipment, Doultons offer an unrivalled service to the electrical engineering world.

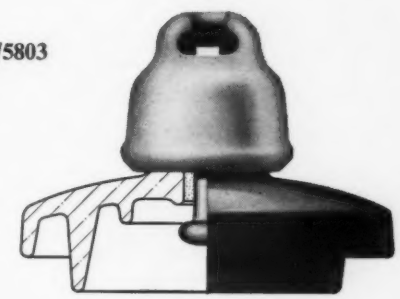
Doulton Insulators are made for standard voltages spanning a range of 400 to 400,000 volts. Many hundreds of thousands are in use to-day over the world's surface.

Three typical designs of high voltage insulators in general use are shown below.

33 kV Pin Insulator, Type BC. 28
Complying with B.S. 137/1960
Minimum Failing Load 2400 lb.



Disc Insulator, Type P.42B/8/5515
Complying with B.S. 137/1960
Minimum Failing Load 42000 lb.



Disc Insulator, Type F.42B/6¾/5803
Complying with B.S. 137/1960
Minimum Failing Load 42000 lb.

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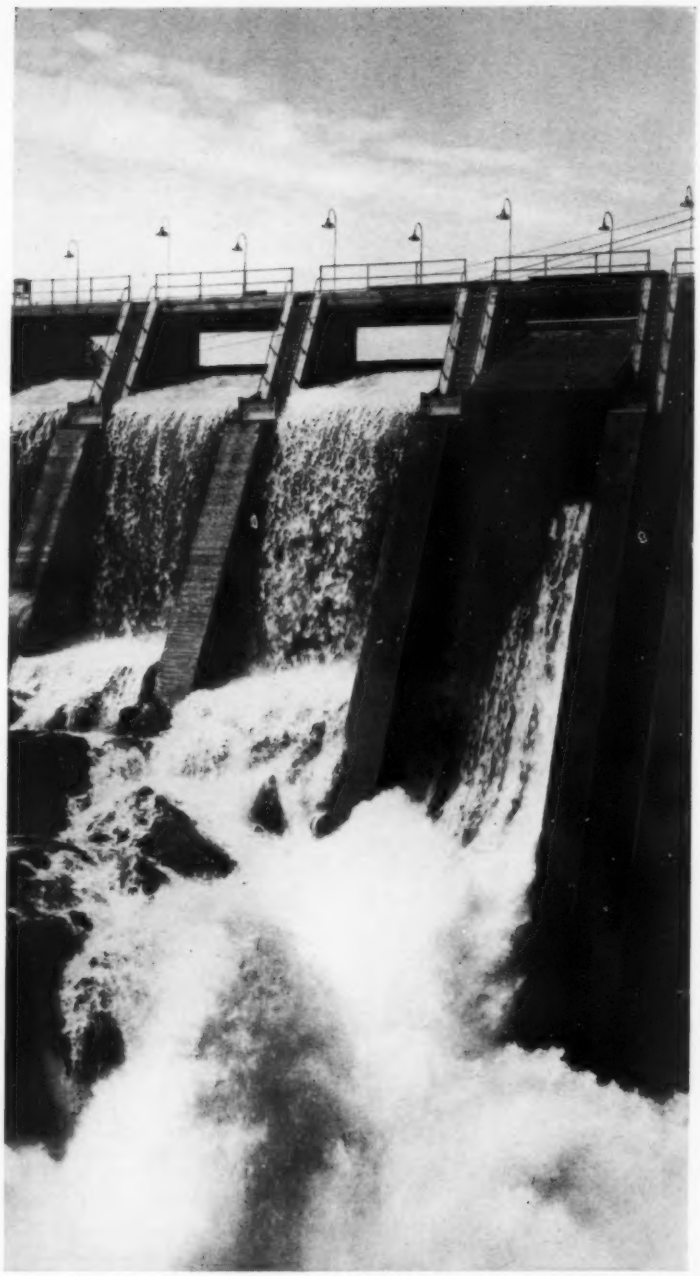
DOULTON INDUSTRIAL PORCELAINS LIMITED

ROYAL DOULTON POTTERIES, WILNECOTE, TAMWORTH, STAFFS.

POWER!



Specialists in all phases of water power development, Kuljian's Hydroelectric Division offers a choice of services—available singly or in combination.

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Write for additional information.

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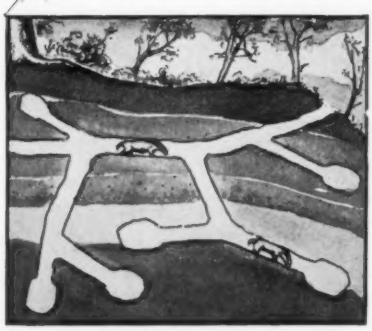
Four 110 000 BHP Francis turbines for the TUMUT 2 Power Station

Underground movement

A long tunneller and a strong tunneller, the badger builds himself an intricate web of passages and dens in which to evade pursuit or retire from the noisy world outside.

It's a paradox of progress that man too—in getting even further away from nature—is going more and more underground. Tunnels for hydro-electric schemes, underground power houses—these and many other engineering feats are the work of man the tunneller—a skill which we have developed into a fine art. * *

* * In driving 58 miles of tunnels for the North of Scotland Hydro-Electric Board, Mitchell Construction captured and hold the World high speed rock-tunnelling record and constructed the first major underground power station in Britain.



Many of these badger 'sets' have been enlarged and improved through successive generations and may extend for hundreds of feet into a hillside.

MITCHELL CONSTRUCTION

Building and Civil Engineering Contractors

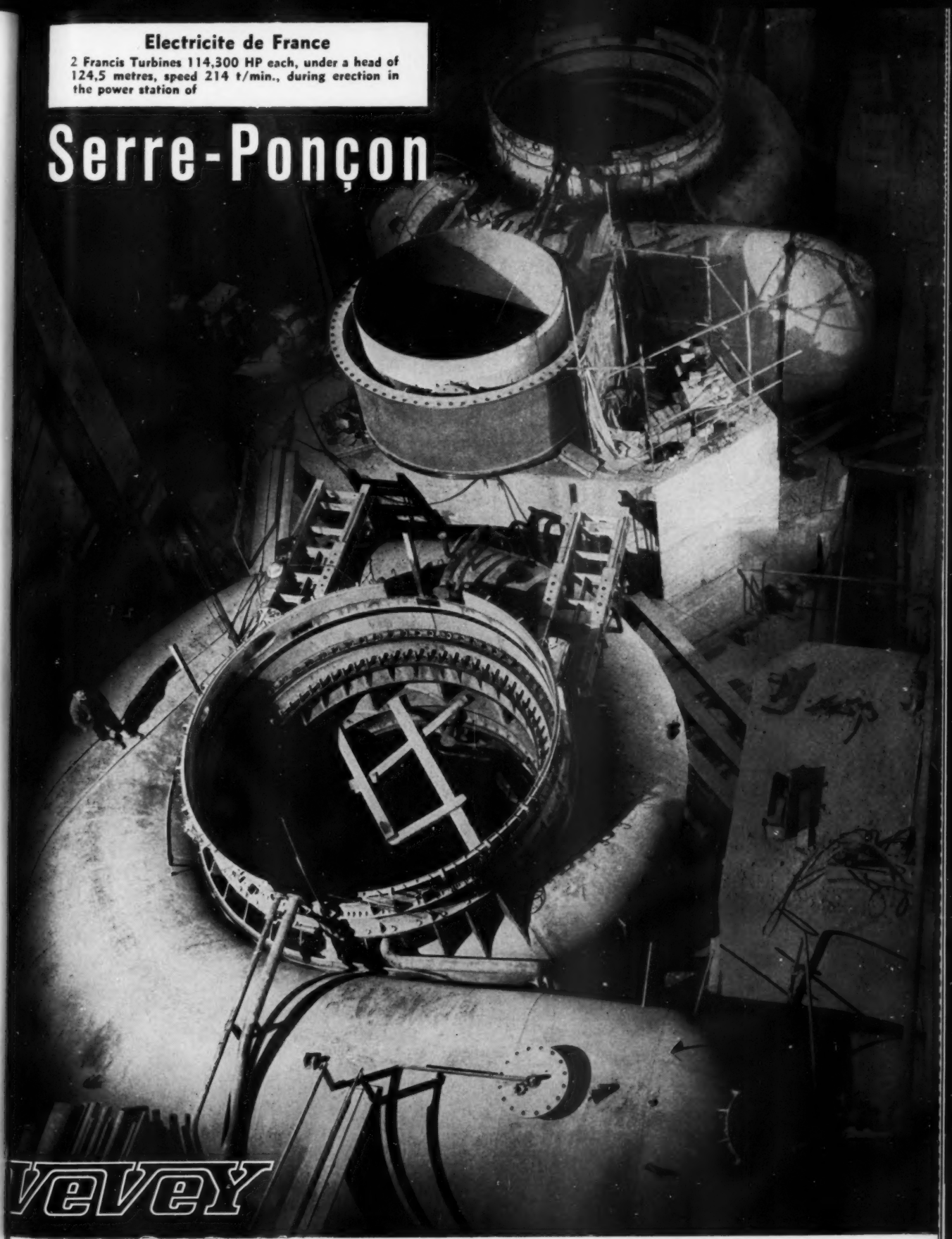
THE MITCHELL CONSTRUCTION COMPANY LIMITED

WHARF WORKS · PETERBOROUGH

Electricite de France

2 Francis Turbines 114,300 HP each, under a head of 124,5 metres, speed 214 t/min., during erection in the power station of

Serre-Ponçon



Vevey Engineering Works Ltd.
Vevey (Switzerland)

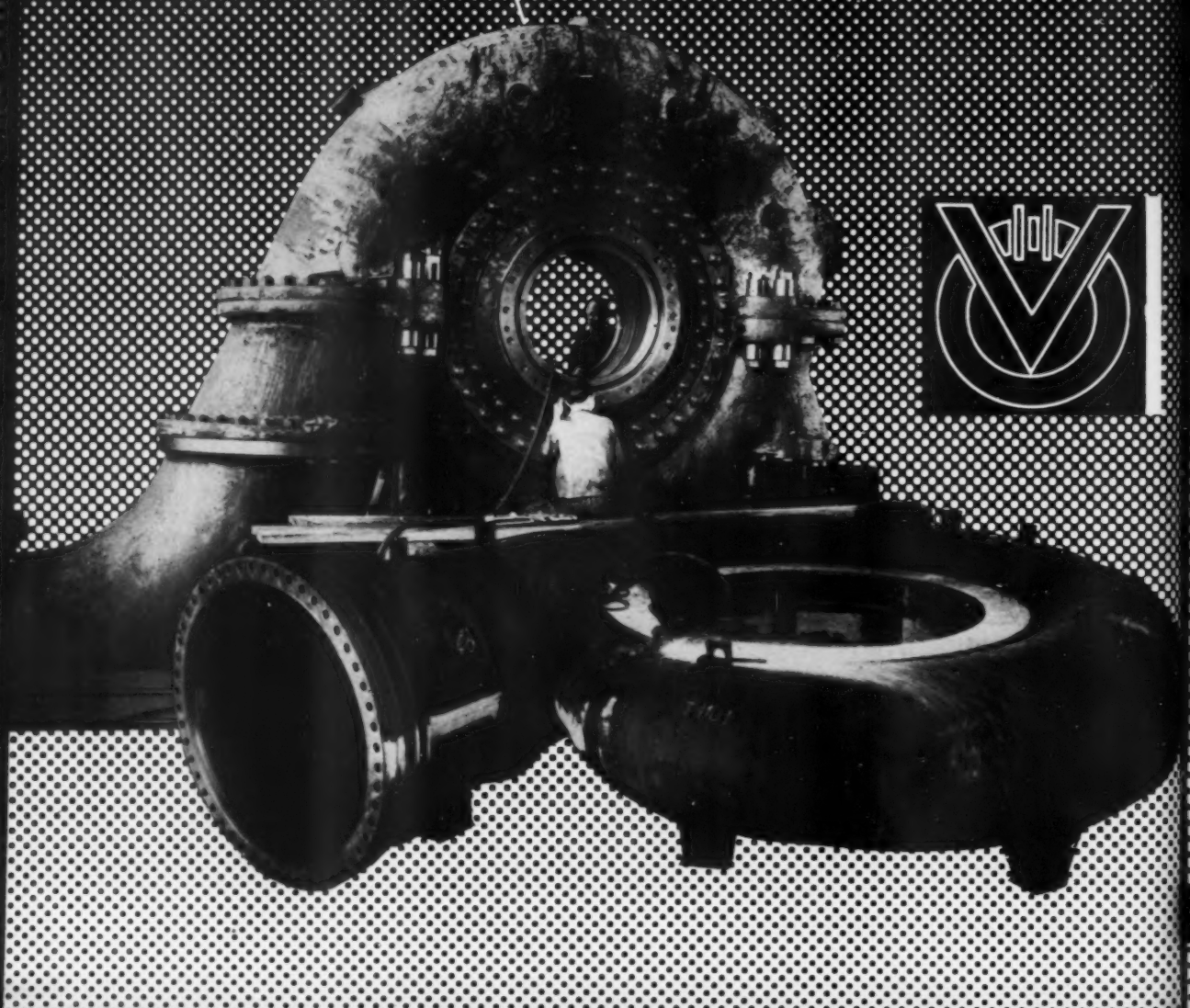
in collaboration with our French licensee:
Cie des Ateliers et Forges de la Loire, St-Chamond (Loire)

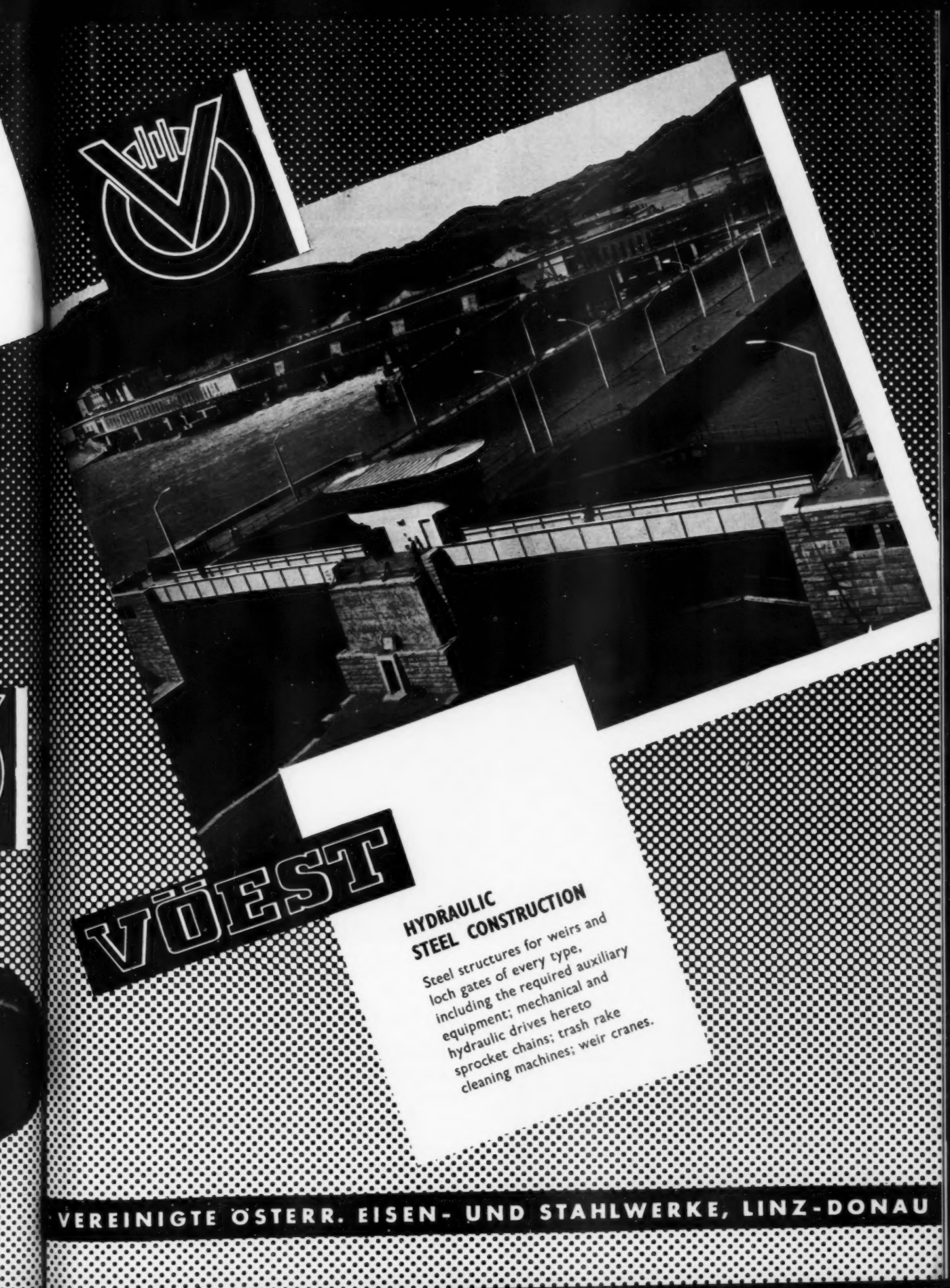
VÖEST

VEREINIGTE ÖSTERREICHISCHE EISEN- UND STAHLWERKE, LINZ-DONAU, AUSTRIA

Hydraulic Turbines, Spherical and Butterfly Valves

Licensed by Baldwin-Lima-Hamilton Corp.
Philadelphia, U.S.A.





VÖEST

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Steel structures for weirs and loch gates of every type, including the required auxiliary equipment; mechanical and hydraulic drives hereto sprocket chains; trash rake cleaning machines; weir cranes.

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Laksapana Power Plant (Ceylon) : Penstocks

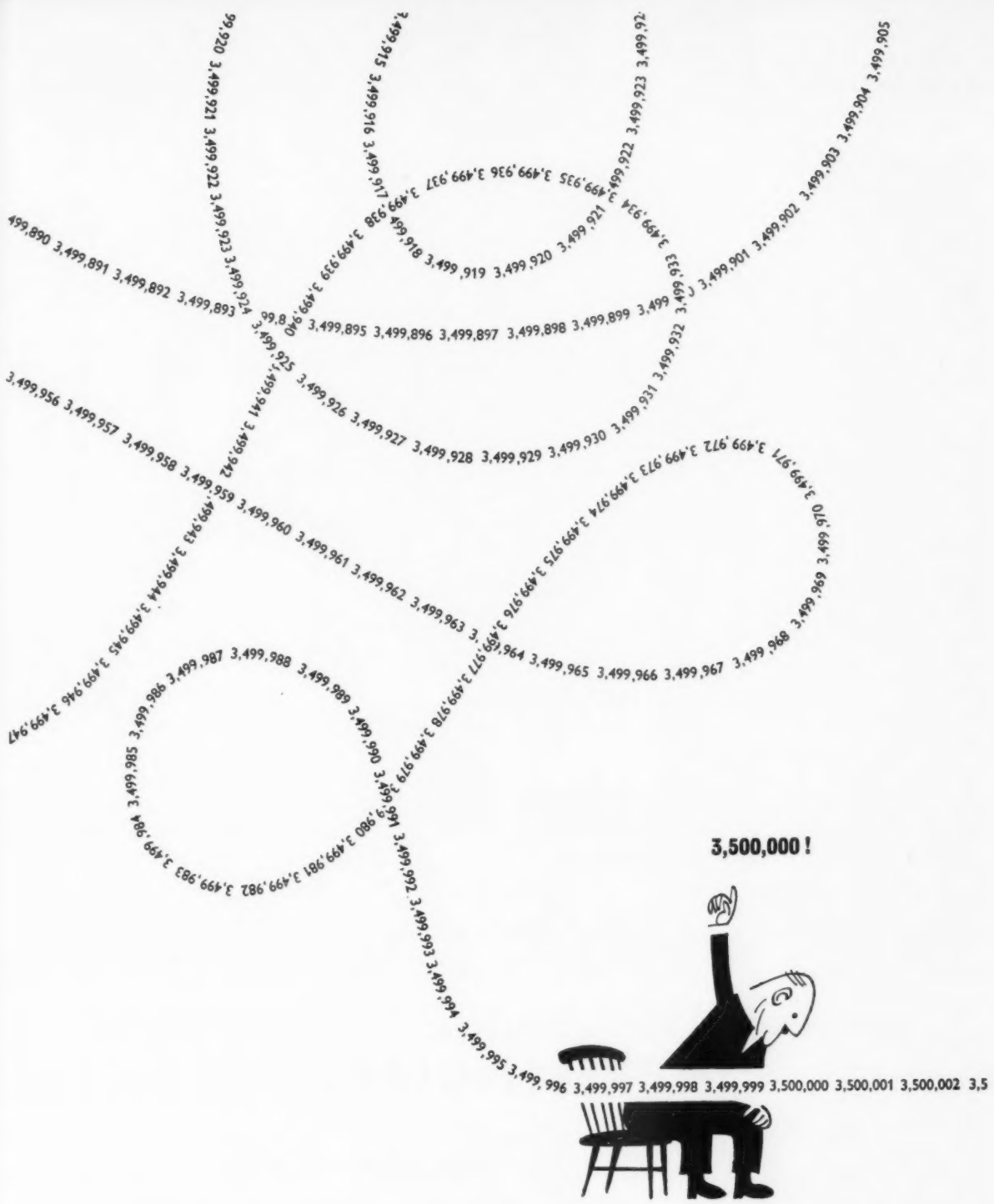
Serre-Ponçon Dam Project : concrete gallery extending over 7,000 ft.

Laksapana Power Plant : Two 16,100 kW Pelton units under erection

CONSTRUCTION AND ERECTION OF ANY HYDRAULIC POWER PLANT EQUIPMENT

Penstocks, Valves, Turbines, Alternators, Electric Switchgear, Transformers, etc...

CIVIL ENGINEERING WORK



3½ MILLION FEET DRILLED WITH VICTOR DRILL STEELS ON HYDRO-ELECTRIC CONTRACT IN 12 MONTHS

Victor Products (Wallsend) Limited, Wallsend-on-Tyne. **Victor** *'Phone: Wallsend 628331/6.*
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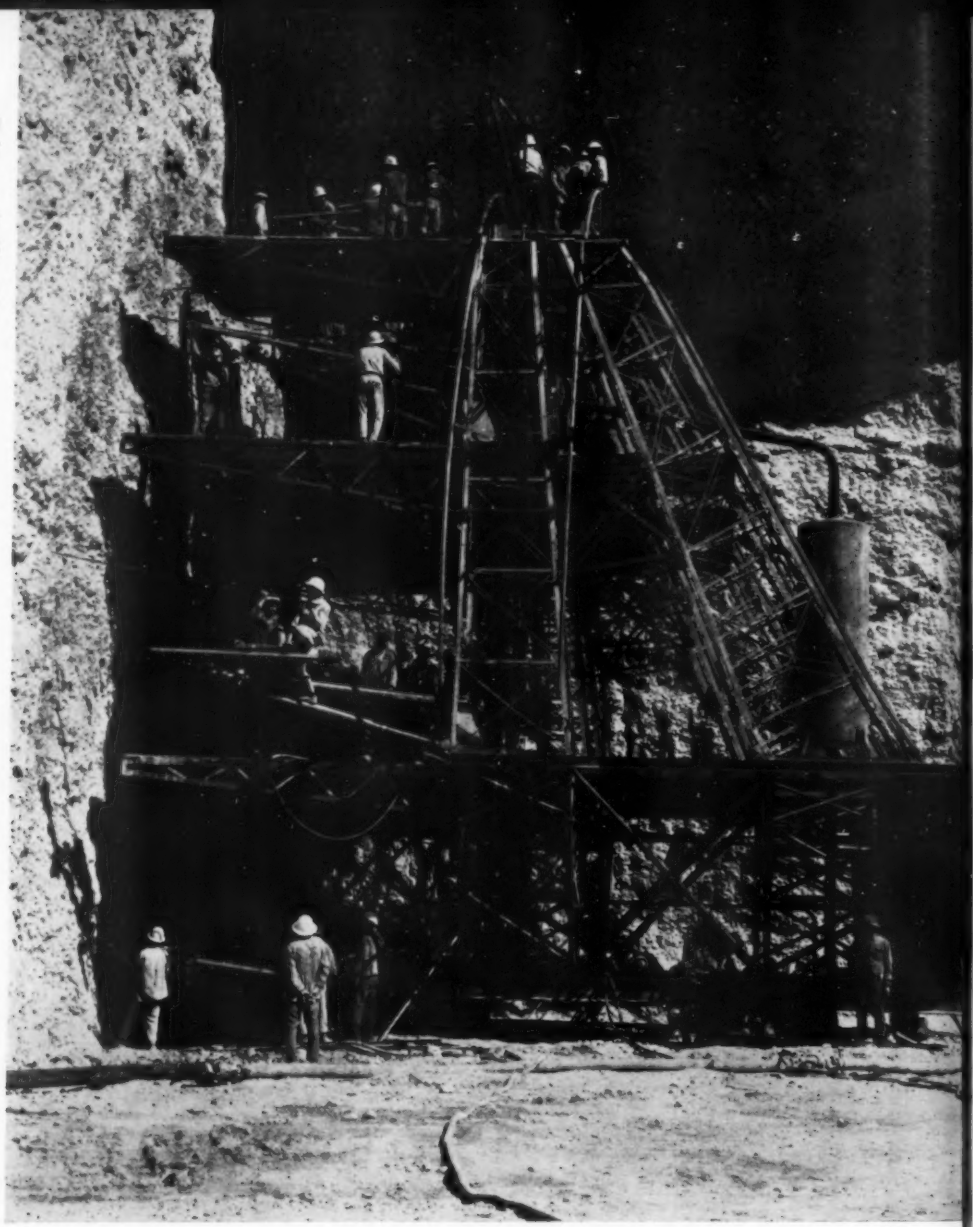

HYDROELECTRIC PROJECT
ON THE DEZ RIVER—IRAN

CIVIL WORKS CARRIED OUT BY IMPRESIT-GIROLA-LODIGIANI IN JOINT VENTURE WITH K.G.T.—TEHERAN

IMPRESIT-GIROLA-LODIGIANI

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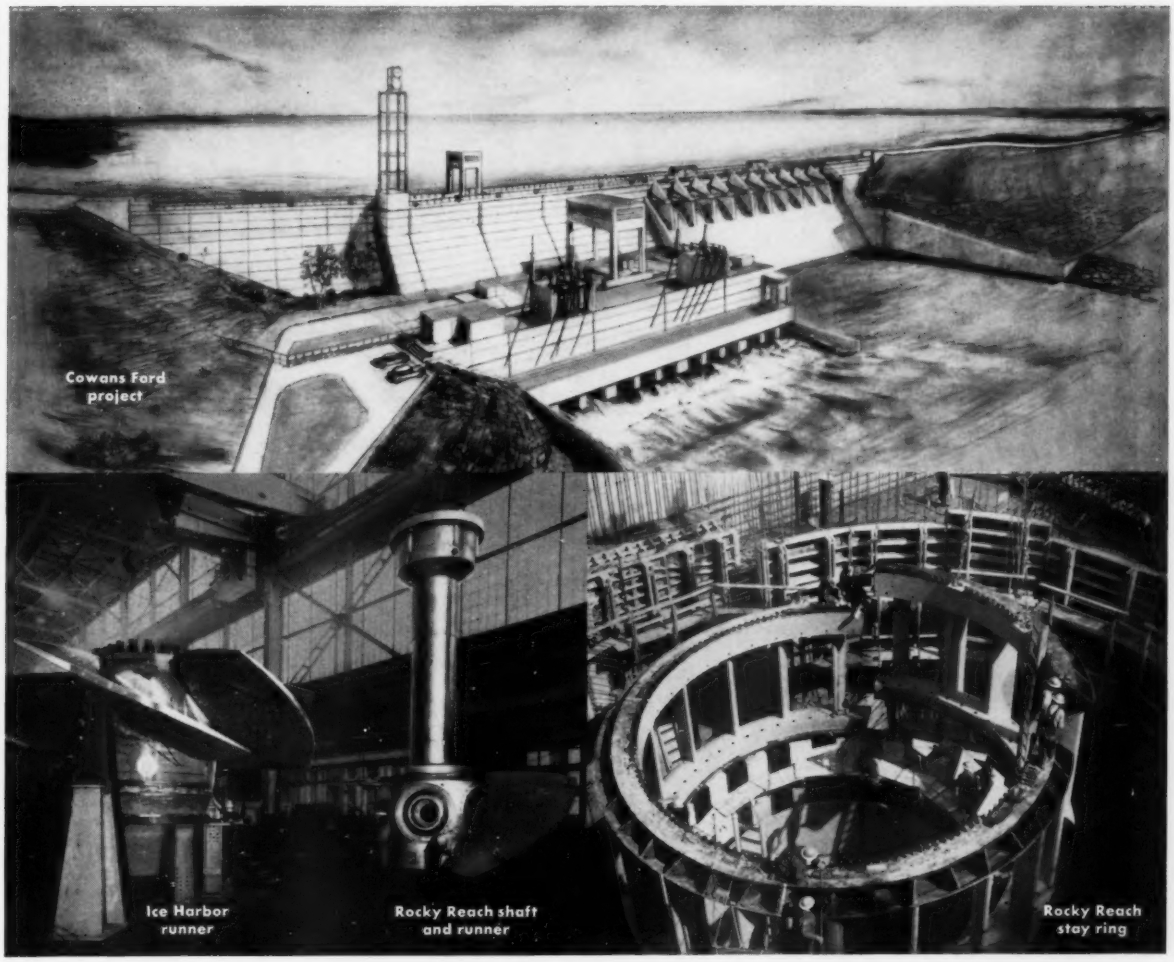
ALLIS-CHALMERS



high-head Kaplans for peaking

—previous record-breakers also by Allis-Chalmers

Cowans Ford is the outstanding illustration of Kaplan turbines used to provide peaking capacity. Duke Power Company, with Chas. T. Main Inc. as consulting engineers, has selected A-C Kaplan turbines for operation at 115-ft. head. Each of the three units is guaranteed to provide a maximum of 153,000 hp. Actual operation will involve only a short time each day, meeting peaking requirements of the system which is predominantly steam. The resulting average load factor, *less than 5%*.

KAPLAN RECORD-BREAKERS

Cowans Ford—the third in a series of outstanding A-C Kaplan turbine installations. These units exceed those at both Ice Harbor and Rocky Reach in rated capacity and head. All are similar in construction (those at Cowans Ford are slightly smaller in physical size). Allis-Chalmers diversified experience to date includes over 240 Kaplan turbines — *a record 6 million hp.*

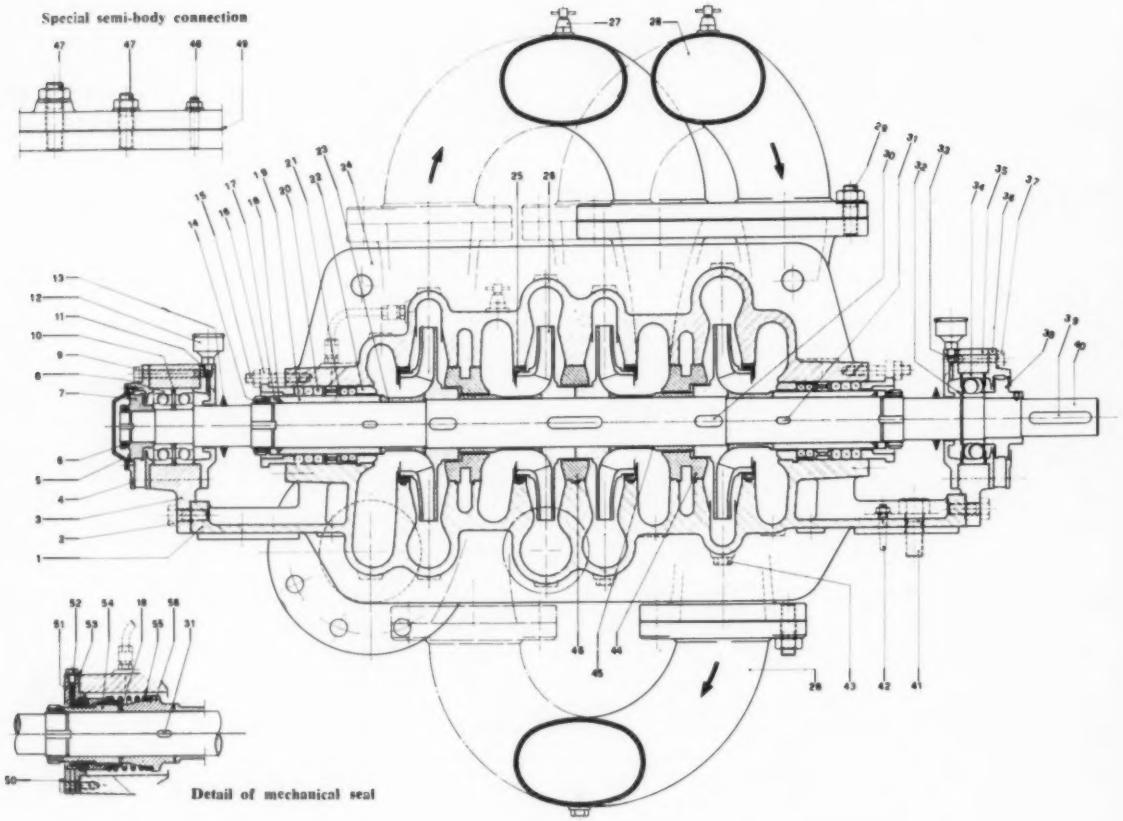
Rocky Reach—public utility district supplied with seven Kaplan turbines, each 140,000 hp (under 92-ft. head).

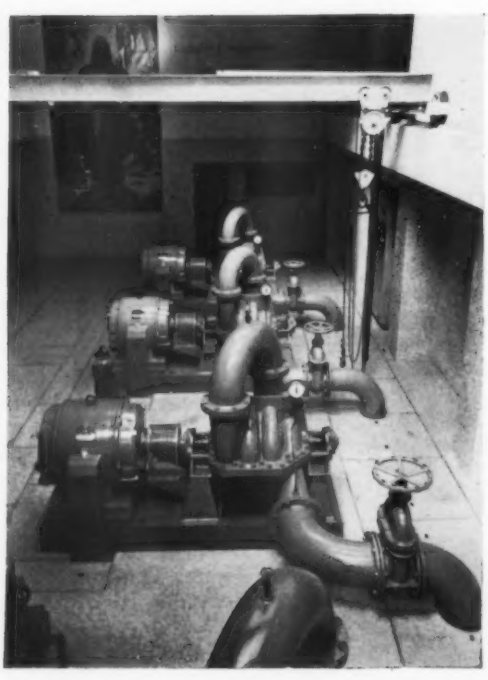
Ice Harbor — Corps of Engineers installation recently provided with three new A-C Kaplans for operation at 89-ft. head. These held the record with 143,000 hp per turbine until Cowans Ford.

In every facet of hydro generation, people count on record performance and experience from Allis-Chalmers. For assistance anytime, contact your local A-C representative or write to **Allis-Chalmers,** Hydraulic Division, York, Pa. A-1383

PD Pump

For water works, storage plants, industrial works, pumping plants.





PD pumps are of the horizontal shaft, single-suction, multi-stage, centrifugal type. Heavy built, these pumps are highly efficient and have every mechanical feature to assure long trouble-free service.

The body of the pump is split in two halves along the horizontal centerline; therefore, it can be easily inspected and quickly dismantled without removing the pump and disturbing the suction and discharge pipe connections. The impellers are in series and opposed in sets, so as to balance the hydraulic pressures. Axial loads on the bearings are thus eliminated, resulting in a more reliable and trouble-free operation of the pump.

The shaft is of high-strength steel and it is lined with protective sleeves where facing the wearing faces of the stuffing boxes with adjustable stuffing glands. Deep boxes accommodate large packing rings. Suitable connections to the sealing supply line are also provided.

Bearing housings of the outboard type, are provided with grease-lubricated heavy duty ball or roller bearings and thrust bearings, for residual or accidental thrusts.

Photo on the left: 2 pumps, type PD 250/300/2, driven by 300 HP NU 2500/4 induction motors, total capacity 24,000 litres (5,280 gallons) per minute, 80-metre (262 ft.) head; 2 pumps, type PD 225/250/2, driven by 200 HP NU 2000/4 induction motors, total capacity 18,000 litres (3,960 gallons) per minute, 80-metre (262 ft.) head. Universal Exhibition Board, Rome.

Please ask for catalogues, price lists, estimates. Our experts are entirely at your service.

Industrie Elettromeccaniche Arzignano - Vicenza - Italy

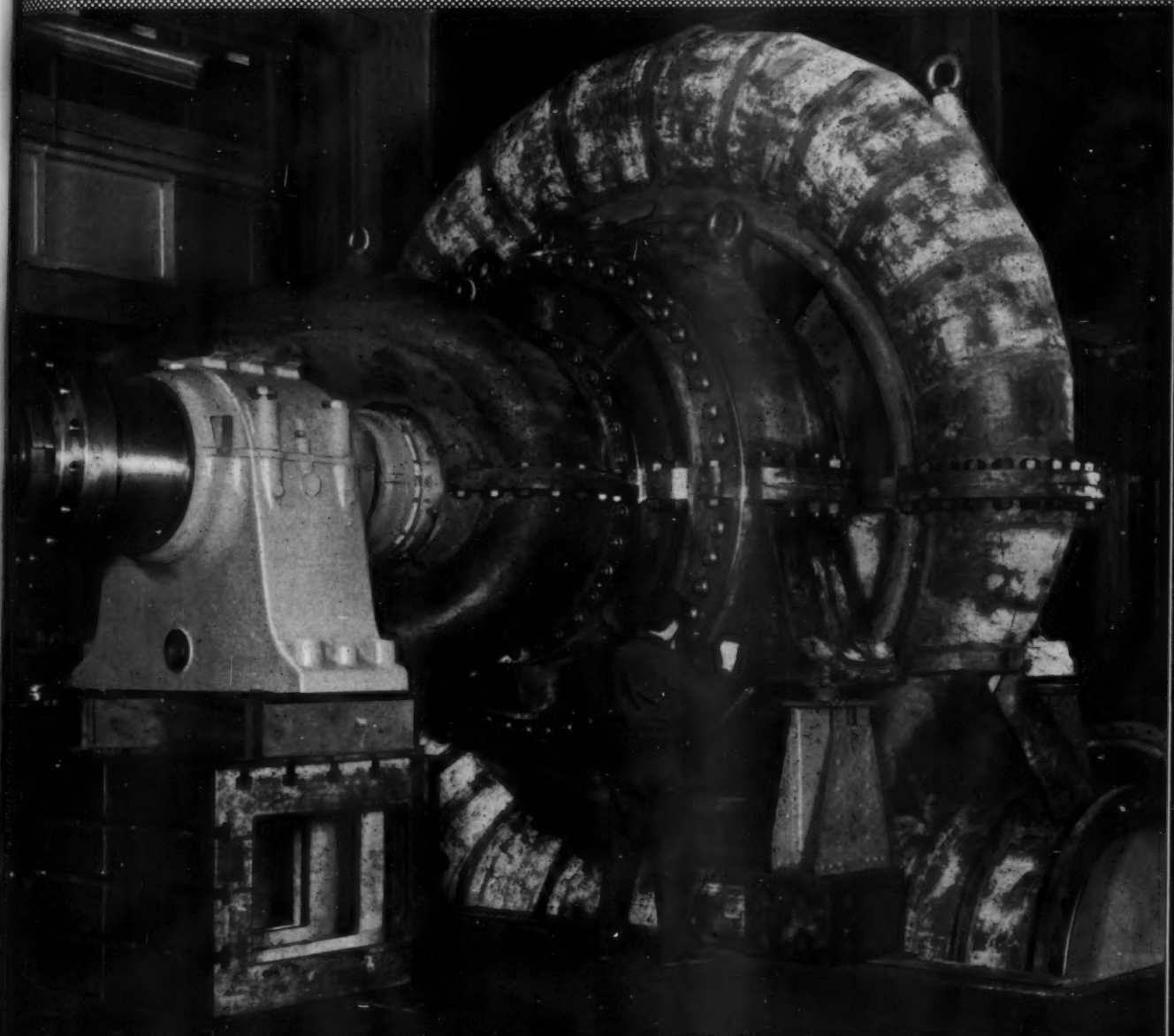
PELLIZZARI

SOCIETA' GENERALE ELETTRICA DELLA SICILIA

GUADALAMI SCHEME

WE ARE SUPPLYING FOR THIS PROJECT:

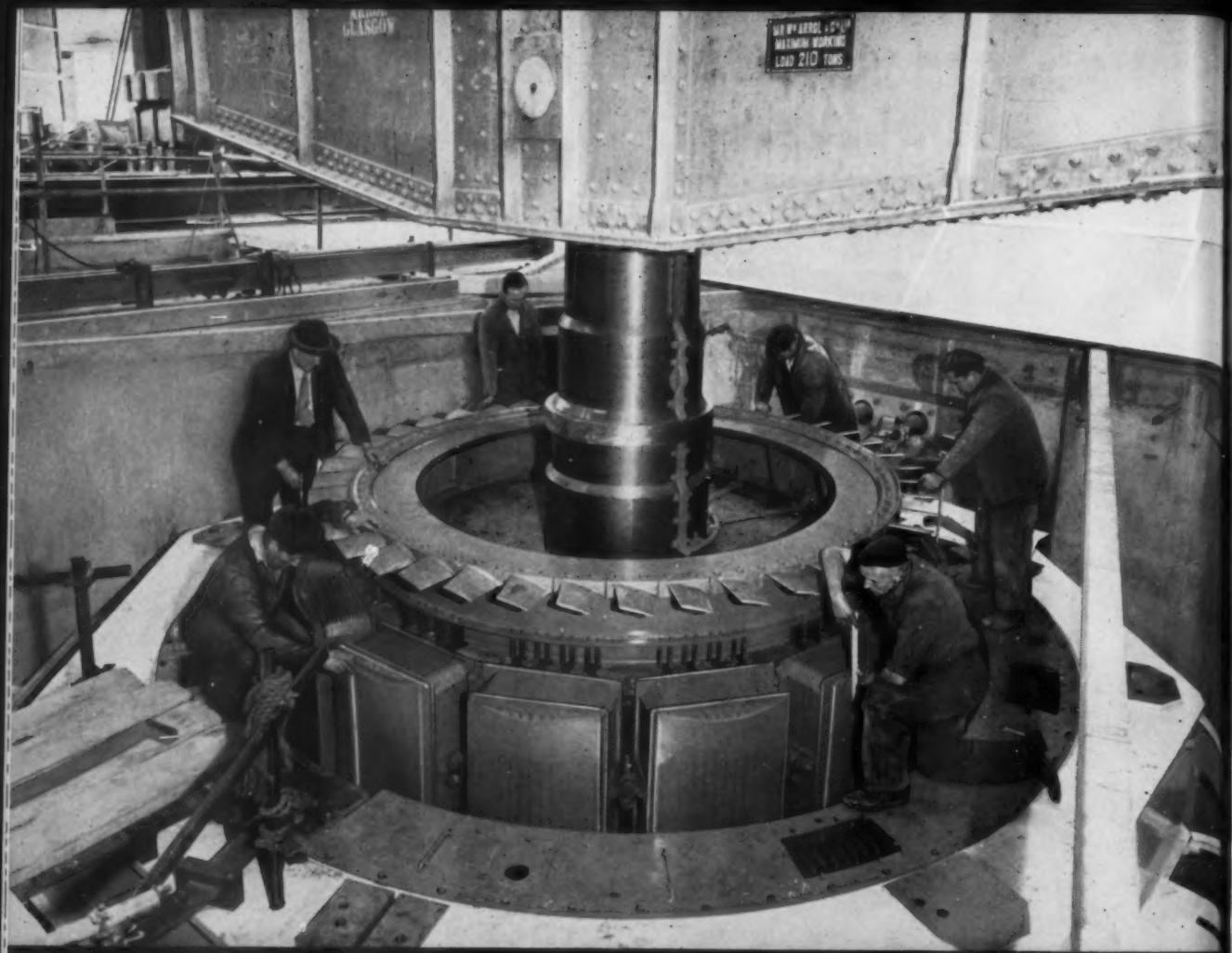
- TWO 40,000 h.p. STORAGE PUMPS
- TWO 43,000 h.p. FRANCIS TURBINES
- ONE 31,000 h.p. FRANCIS TURBINE



RIVA

COSTRUZIONI MECCANICHE RIVA

VIA STENDHAL 34 MILANO ITALY



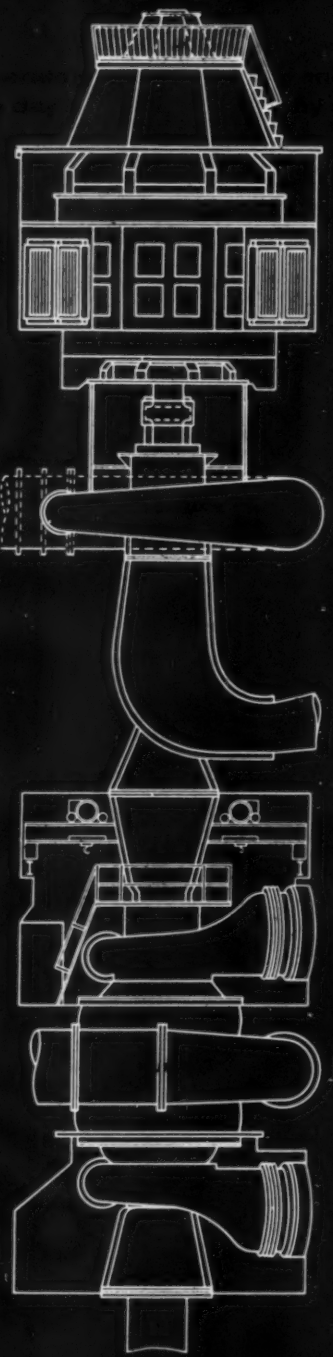
BLAENAU FFESTINIOG

Four 75,000-kW machines supplied by AEI will soon be performing double duty as generators and motors at the C.E.G.B.'s hydro-electric station at Blaenau Ffestiniog, Wales.

By day, water turbines fed from the upper reservoir will drive the AEI machines as generators supplying electricity to the Grid to meet peak loads. After passing through the turbines, the water will be stored in the lower reservoir. At night, when the capacity of the Grid exceeds the demand, the same AEI machines will operate as motors driving pumps to return the stored water to the upper reservoir for further use during the next peak load period.

These dual-purpose machines supplied by AEI Heavy Plant Division are at the very heart of this, Britain's first major pumped storage scheme. In addition, AEI Switchgear Division are supplying the 275-kV motor-driven isolators—which will be used in place of circuit breakers—together with the by-pass isolators, relay and control equipment, feeder protection equipment including control panels, earthing equipment, and multicore cables.

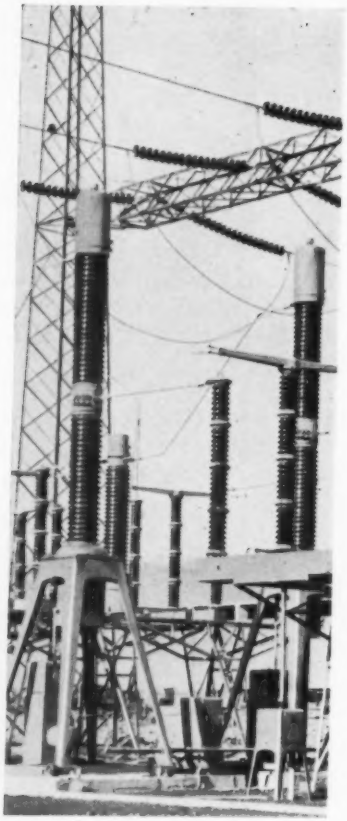
Consulting Engineers: Messrs. Freeman, Fox and Partners and Messrs. Kennedy and Donkin.

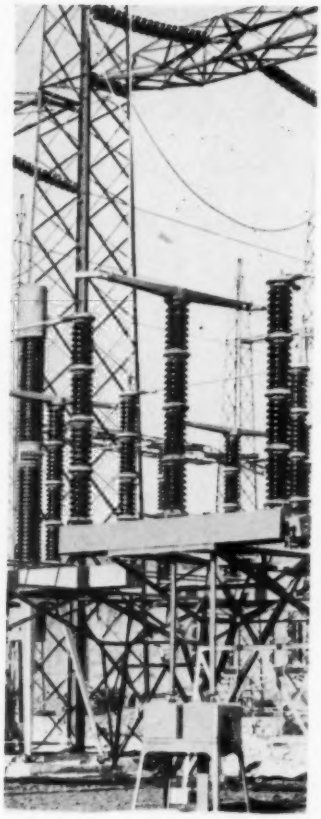


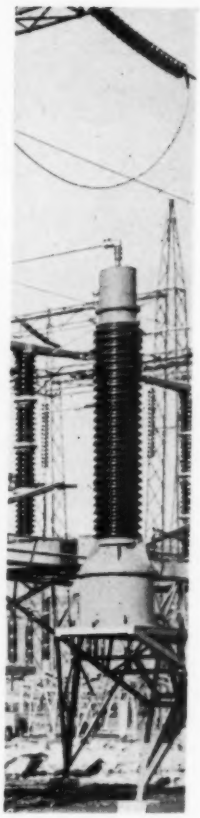
AEI **Associated Electrical Industries Limited**

Heavy Plant Division
RUGBY, WARWICKSHIRE
ENGLAND

Switchgear Division
TRAFFORD PARK, MANCHESTER
ENGLAND







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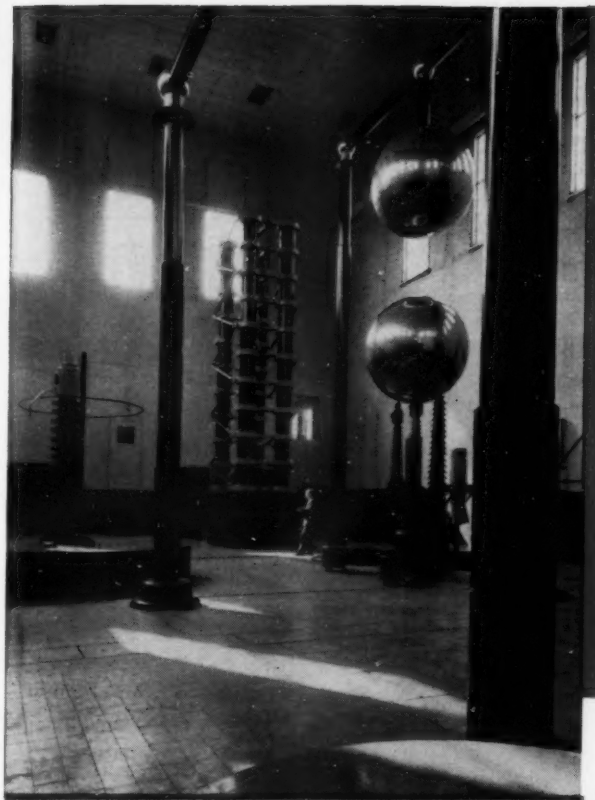
INSTRUMENT TRANSFORMERS
ISOLATING SWITCHES
BUSHING INSULATORS
SWITCHBOARDS
METAL-CLAD SWITCHGEAR

FOR MEDIUM, HIGH
AND ULTRA-HIGH VOLTAGES



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Leading manufacturers use M & I electrical insulating materials because our facilities ensure that all our products are manufactured to the highest standards.

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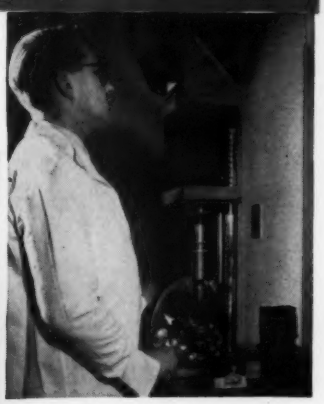
Water-absorption meter— Chemical Laboratory.



ABOVE. Using a Photomicroscope— Research Laboratory.

BELOW. Tabulating thermal characteristics. Insulating materials being placed in high temperature oven— Development Laboratory.

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MICA; block, splittings and fabricated parts.
MICANITE; built-up mica insulation of every type in the form of sheets, tubes, cylinders, V-rings, covered bars.
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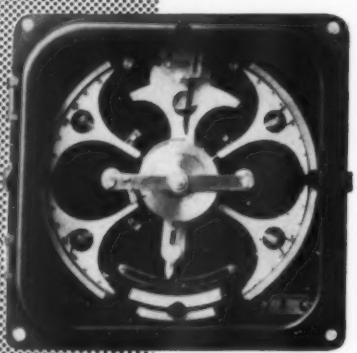
"SAMICA", "PAXOLIN" and "PANILAX" are our registered trade marks *"Terylene" is a registered trade mark of I.C.I.*

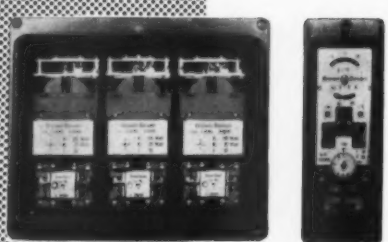
Indispensable in modern power stations

BROWN BOVERI

Brown Boveri airblast circuit-breakers are built from proved, standard components for voltages up to 400 kV and breaking capacities up to 20000 MVA; they ensure stable system operation and protect your installations, machines and apparatus



Brown Boveri quick-acting regulators for the regulation of a.c. and d.c. voltage, current, power, frequency and pressure, require little space and power, no upkeep, only one single setting, and function rapidly and reliably



Brown Boveri generator protection equipment detects widely differing types of faults without risk of undesired tripping and safeguards your generators against disturbances of all kinds

75393-VI E

Brown Boveri power line carrier equipment facilitates supervision and control of your stations. It can be readily adapted to the specified conditions and is economical and ready for service at any time

Our specialists will be glad to advise you

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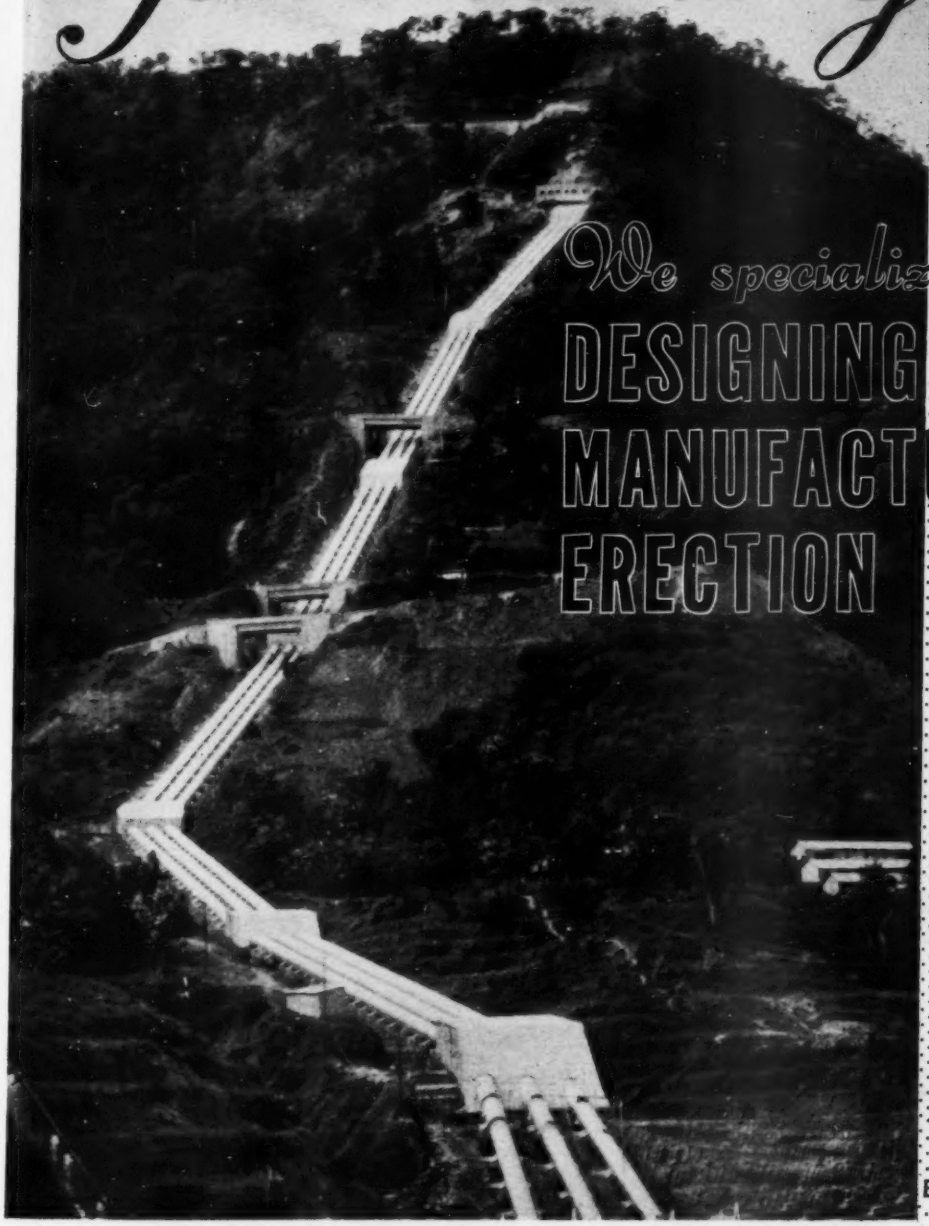

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EQUIPMENT

for Ancillary Works

Flow control equipment is often required for ancillary waterways of hydro-electric schemes, such as subsidiary collecting works, domestic supply lines, and fire-fighting services. For these, as well as for the major features of the projects, all needs can be met from the extensive range of Glenfield Products

A few examples of equipment for ancillary works are illustrated covering sluice, check, butterfly, air and pressure relief Valves, single-faced Sluices and screw-down Fire Hydrants.

Glenfield

GLENFIELD & KENNEDY LIMITED KILMARNOCK

HEAD OFFICE & WORKS:—
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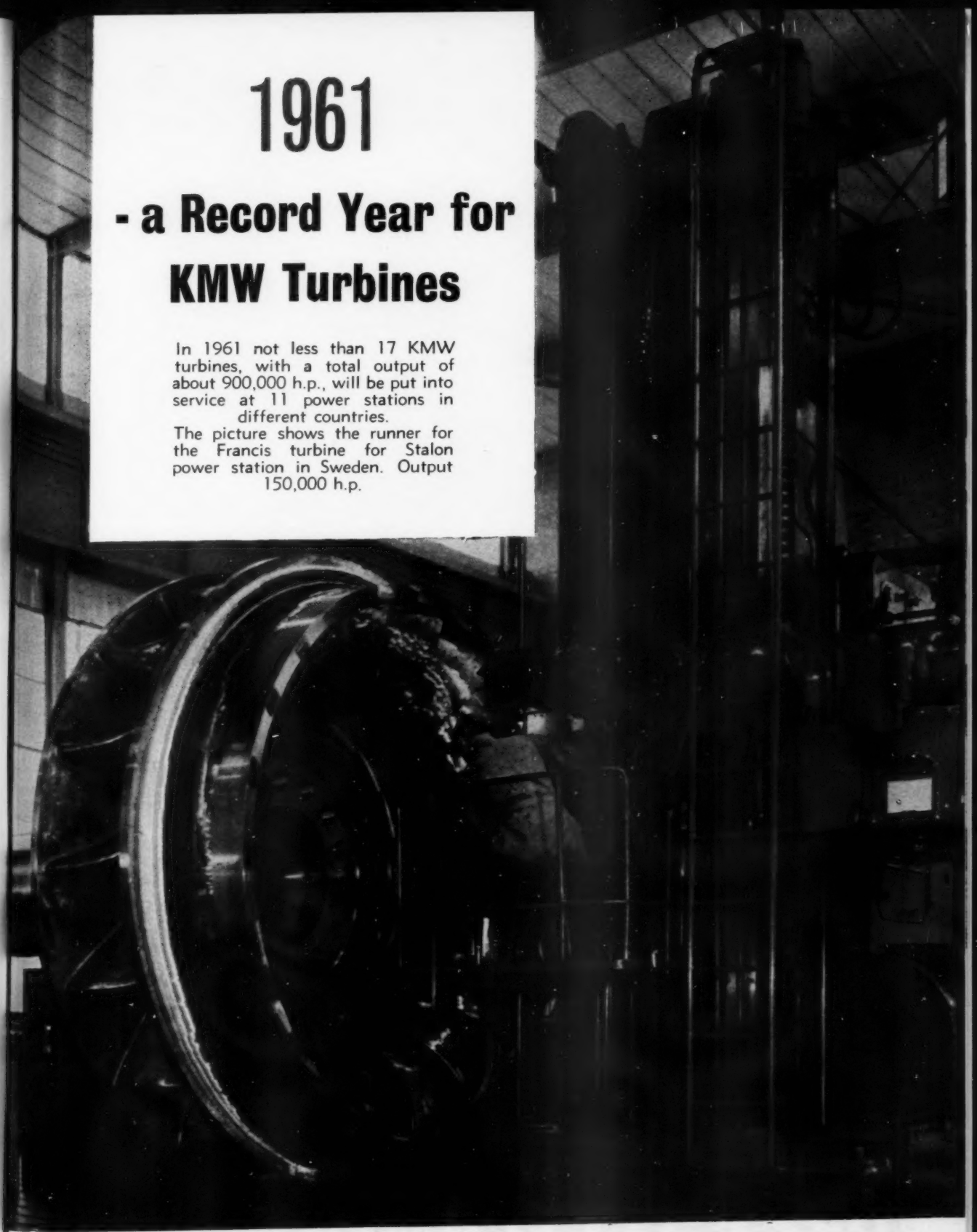
1961

- a Record Year for KMW Turbines

In 1961 not less than 17 KMW turbines, with a total output of about 900,000 h.p., will be put into service at 11 power stations in different countries.
The picture shows the runner for the Francis turbine for Stalon power station in Sweden. Output 150,000 h.p.



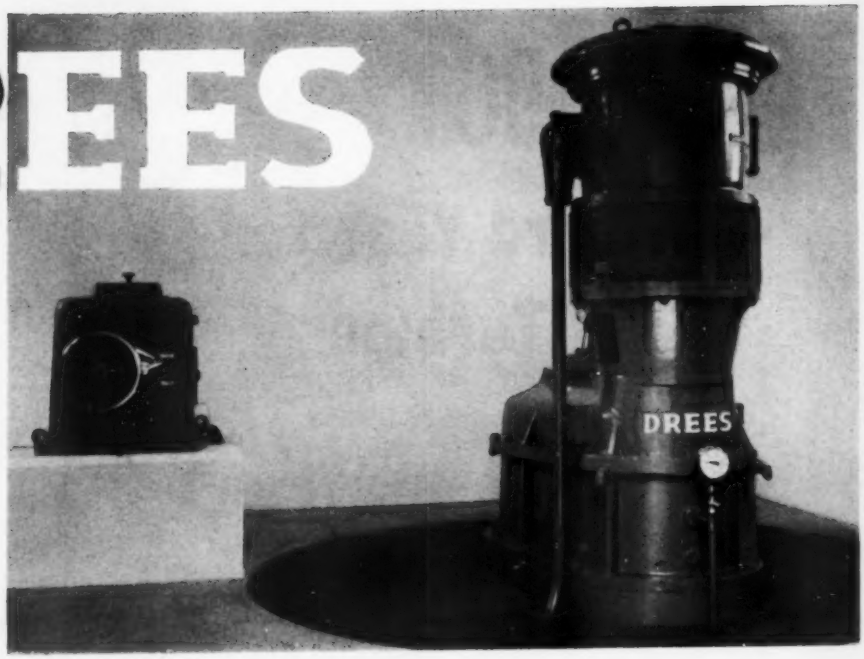
AB KARLSTADS MEKANISKA WERKSTAD

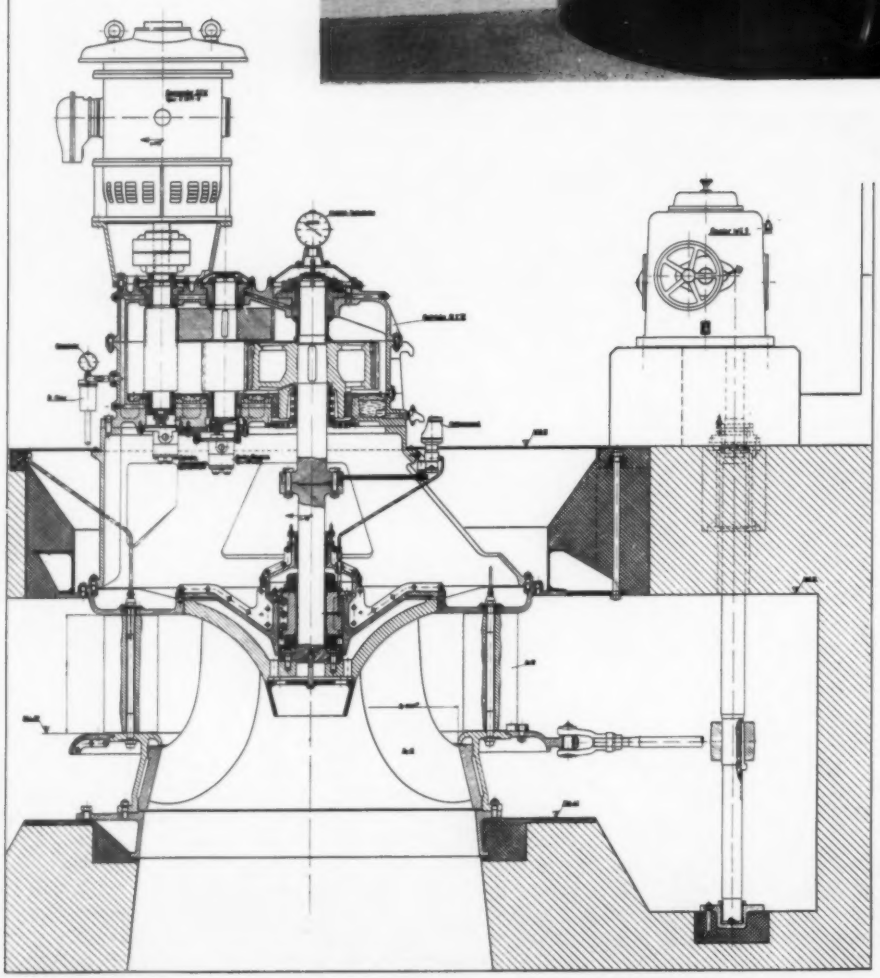
KARLSTAD - SWEDEN

Representatives in Canada: A. Johnson & Co. Ltd., P.O. Box 56, Montreal 16

KMW

DREES





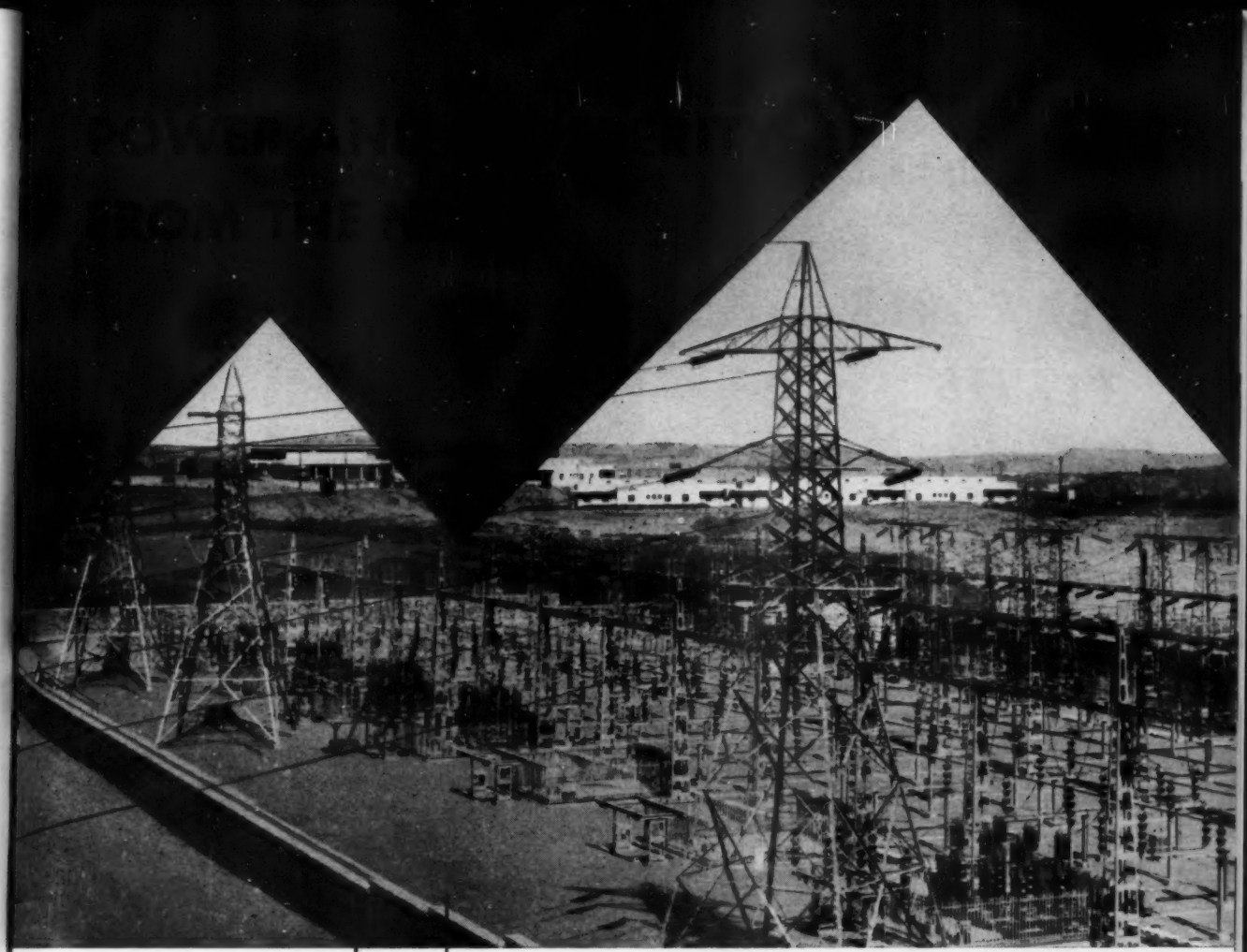
DESIGNS AND CONSTRUCTS:

FRANCIS,
KAPLAN,
AND
PELTON
TURBINES
WITH HORIZONTAL AND VERTICAL SHAFTS

HYDRAULIC SPEED, HEAD WATER LEVEL AND SAFETY GOVERNORS

FLOW CONTROL EQUIPMENT GEARS

DREES + CO. GMBH WERL, WESTFALEN WESTERN GERMANY



The Nile, the life blood of Egypt, is now harnessed at Aswan to provide power for the needs of the nation.

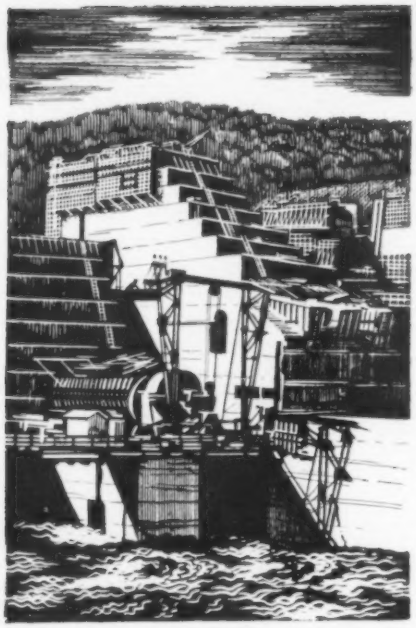
In addition to supplying two 49.5 MVA generators and all power transformers for this huge project ASEA has also furnished all switchgear, auxiliary apparatus, cables and steel structures for the 132 kV switching station.

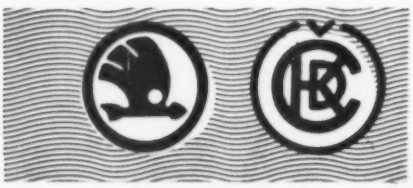
For complete
power installations —

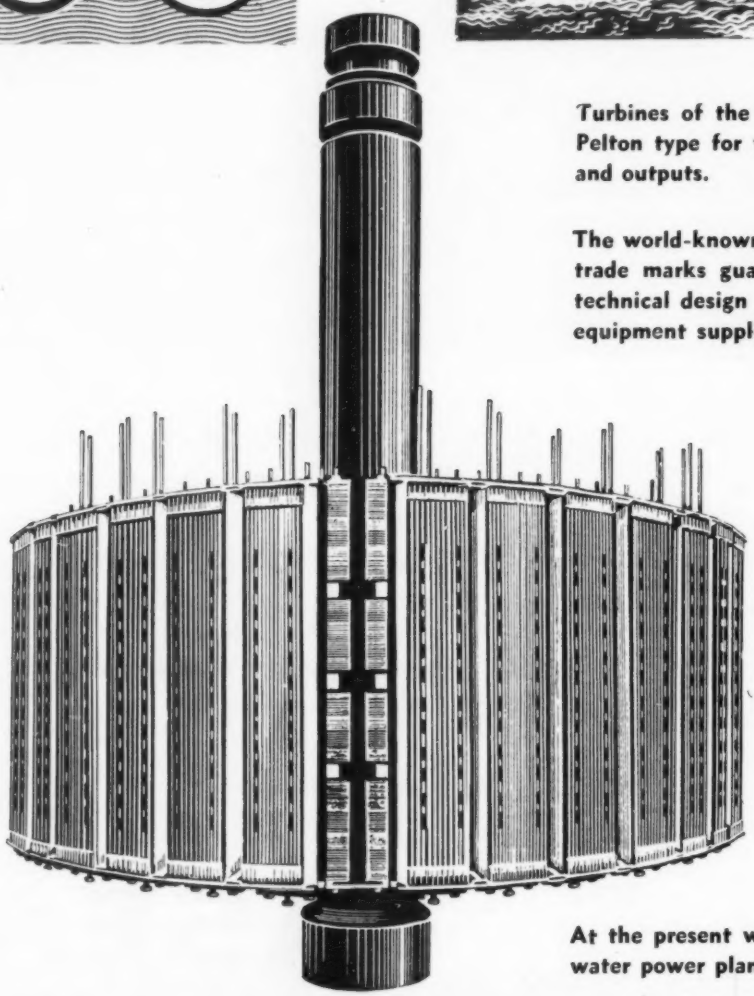
ASEA

Västerås Sweden

Complete Equipment for WATER POWER PLANTS







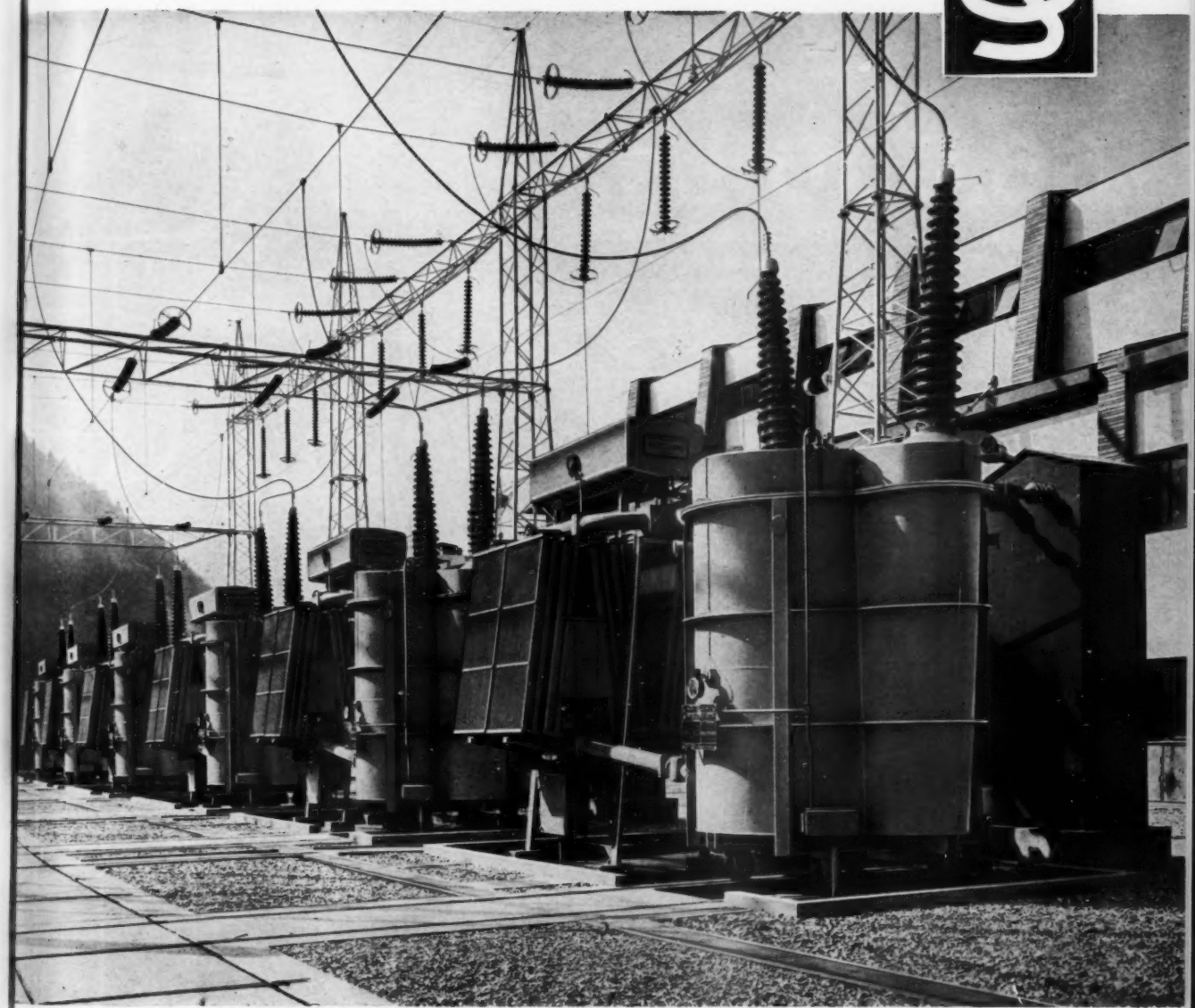
Turbines of the Francis, Kaplan and Pelton type for various heads and outputs.

The world-known Škoda and ČKD trade marks guarantee the first-class technical design and quality of equipment supplied by us.

At the present we are constructing water power plants in 10 states.

TECHNOEXPORT

Foreign Trade Corporation for Export of Complete Industrial Plants
PRAHA, Czechoslovak Socialist Republic

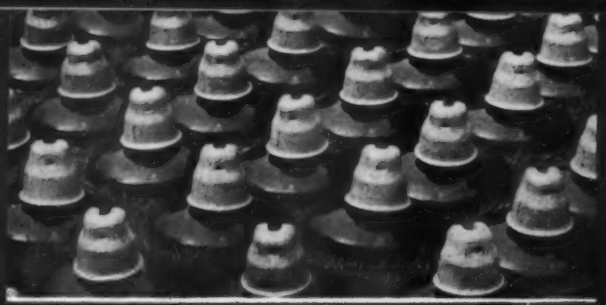


Six single-phase transformers, cooled by separately mounted radiators, forming two 75 MVA three-phase banks, ratio 11 ± 5% / 260 kV. These transformers have been supplied to C.E.B. (Consorzio Elettrico del Buthier), Turin, Italy, for the Valpelline power station; and they have the highest voltage in the Aosta Valley power system.

società nazionale delle officine di

savigliano

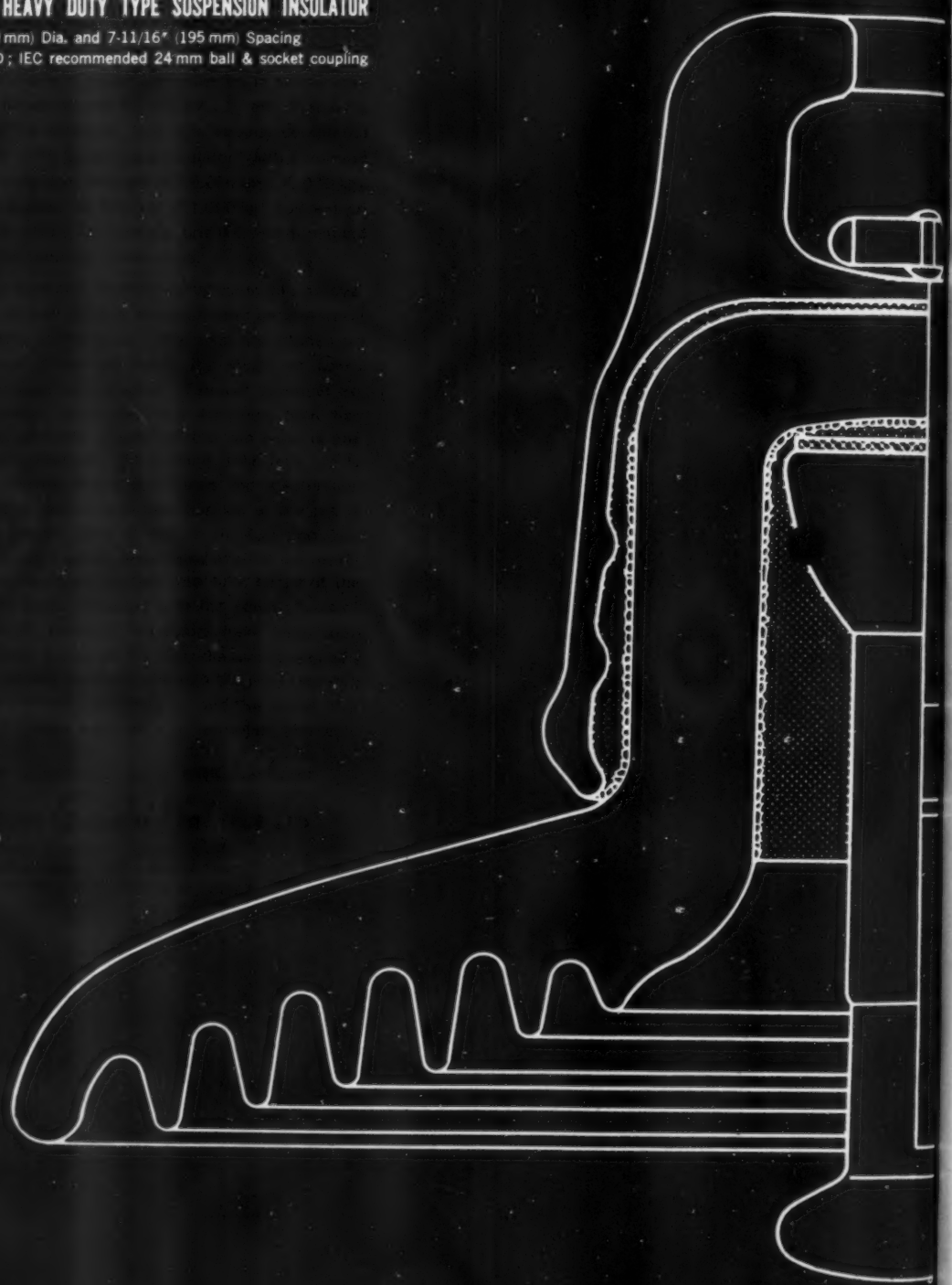
Corso Mortara 4 - TORINO (ITALIA)



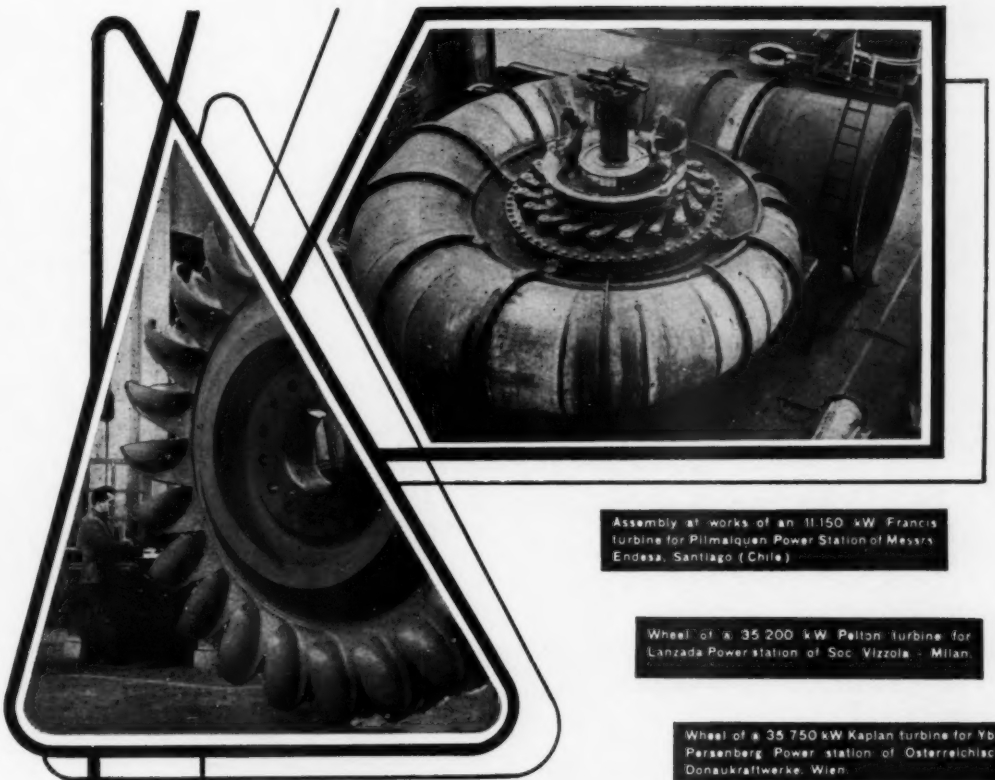
66,000lbs.

(30,000 kg) EXTRA HEAVY DUTY TYPE SUSPENSION INSULATOR

12-5/8″ (320 mm) Dia. and 7-11/16″ (195 mm) Spacing
NGK Cat. No. CA-590ND ; IEC recommended 24 mm ball & socket coupling



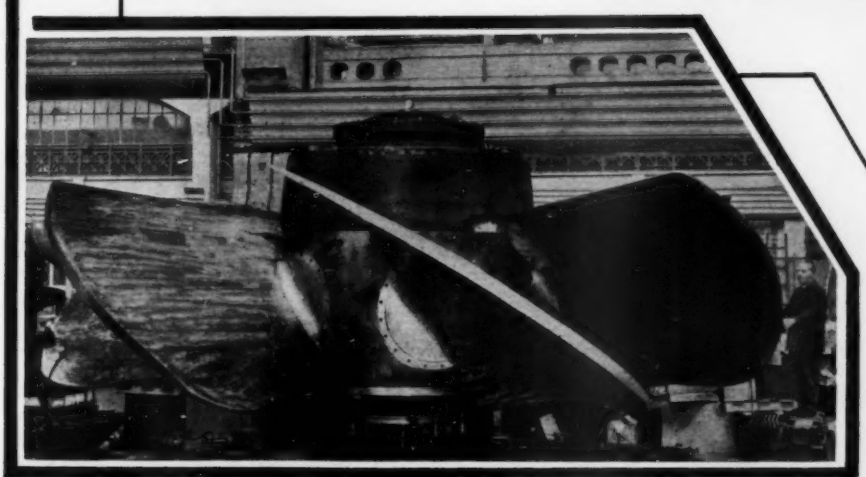
Complete hydro-electric plants



Assembly at works of an 11.150 kW Francis turbine for Pilmalquen Power Station of Messrs Endesa, Santiago (Chile)

Wheel of a 35.200 kW Pelton turbine for Lanzada Power station of Soc. Vizzola - Milan.

Wheel of a 35.750 kW Kaplan turbine for Ybbs Persenberg Power station of Osterreichische Donaukraftwerke, Wien.



ANSALDO-SAN GIORGIO
GENOVA

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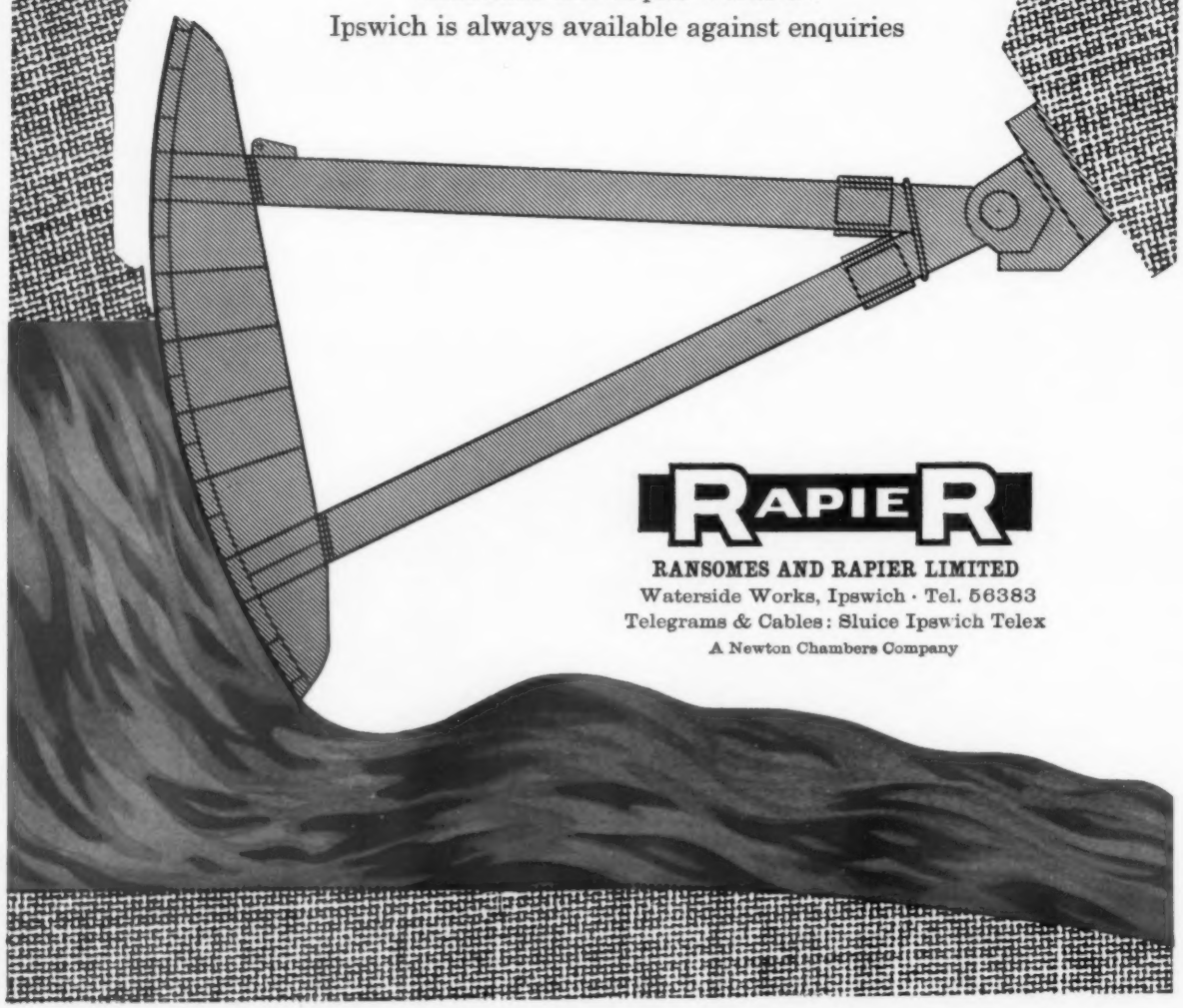
RapieR engineers can draw on 80 years' world-wide experience when designing, manufacturing and installing hydraulic sluice structures for power stations, turbine intakes, draft tubes, dam culverts and spillways — as well as for irrigation, flood control and water supply. This experience added to the comprehensive technical resources of the Ransomes and Rapier works at Ipswich is always available against enquiries



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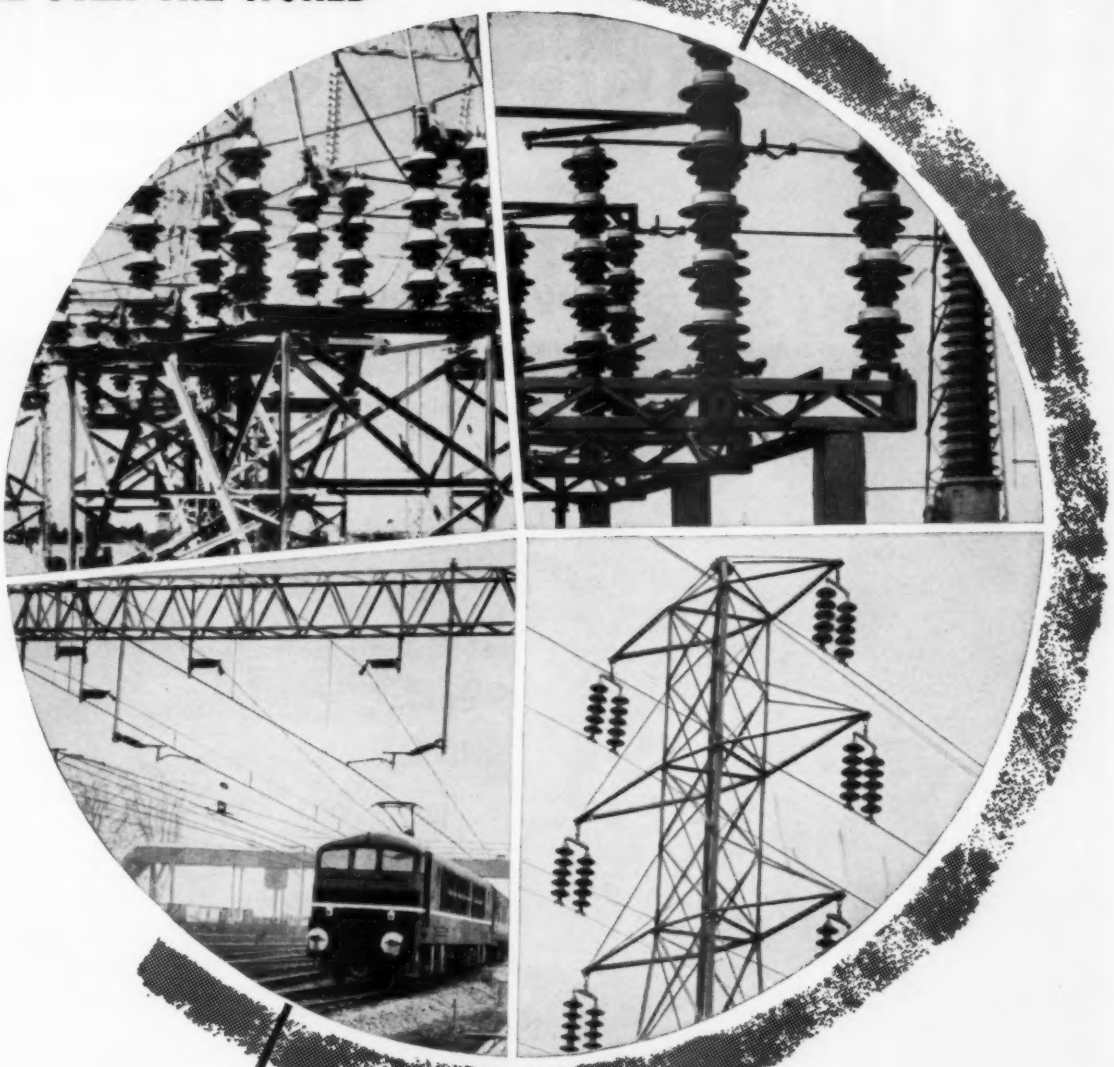
ALL OVER THE WORLD



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HIGH VOLTAGE INSULATORS

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Switchgear post insulators
Transformer bushings
Insulators for railway electrification
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SP108

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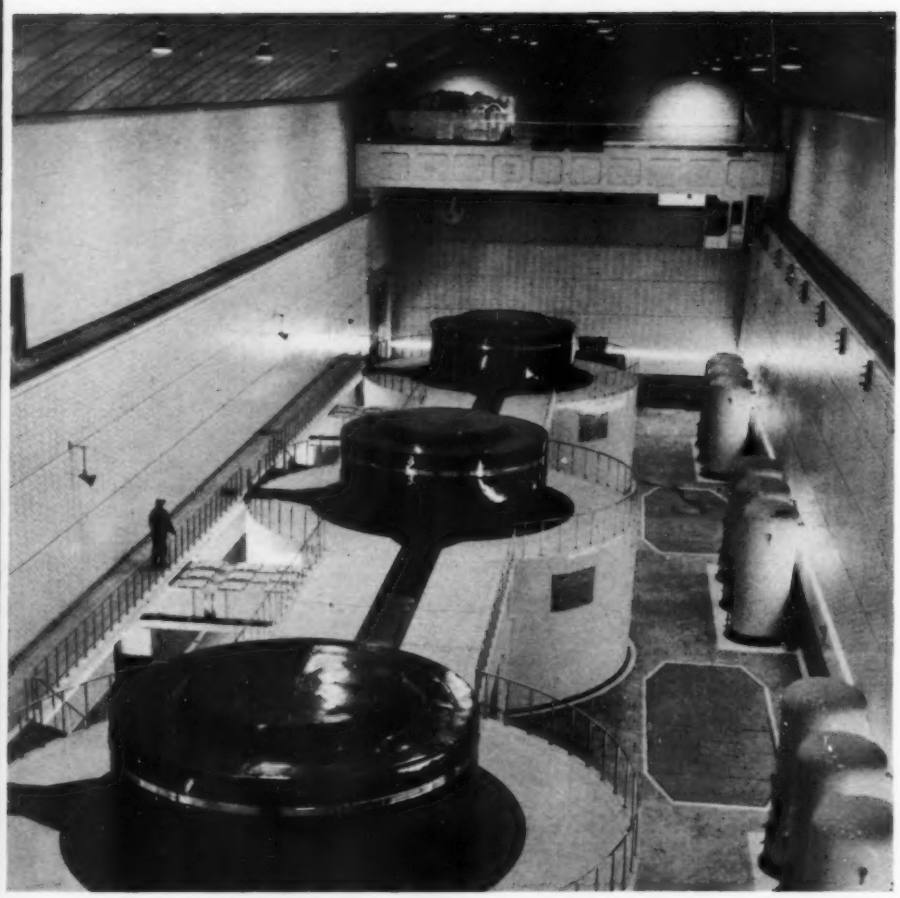

Boosting Japan's electrical power capacity for her busy industries is the mission of these huge generators. This autumn they'll each begin generating 133,000 kVA—enough power to bring progress to an area of twenty million people. They were built by Toshiba, where 85 years' accumulated experience is daily translated into thousands of quality electrical products for home and industry throughout the world.

Toshiba

TOKYO SHIBAURA ELECTRIC CO., LTD.

Tokyo, Japan Cable: TOSHIBA TOKYO

VOITH

Four 100,000-hp pumps, two 145,000-hp turbines for Vianden

Three 37,500-hp pumps, three 47,000-hp turbines for Reisach

Two 45,000-hp pumps, two 50,000-hp turbines for Happurg

Two 46,000-hp pumps for Glems

One 30,000-hp pump, one 38,000-hp turbine for Tanzmühle

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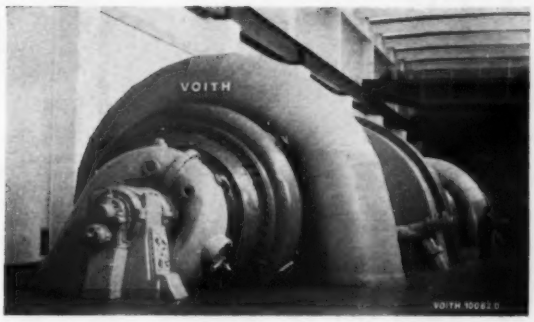

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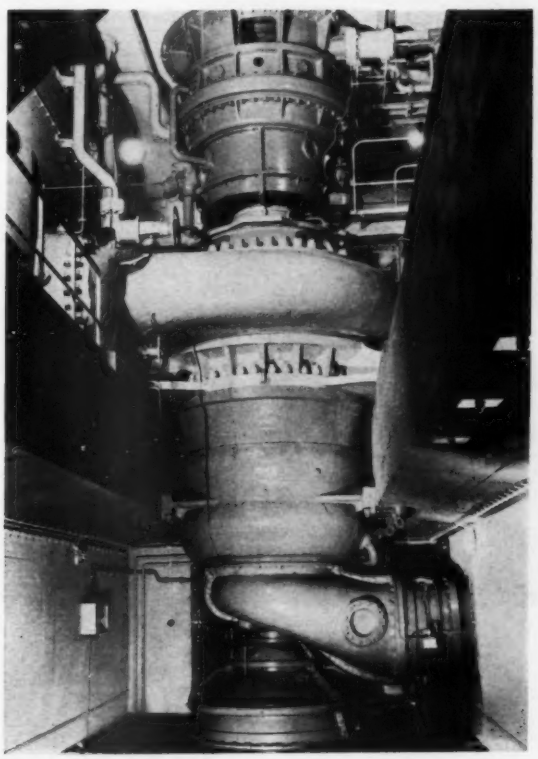

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Volume 13 Number 10

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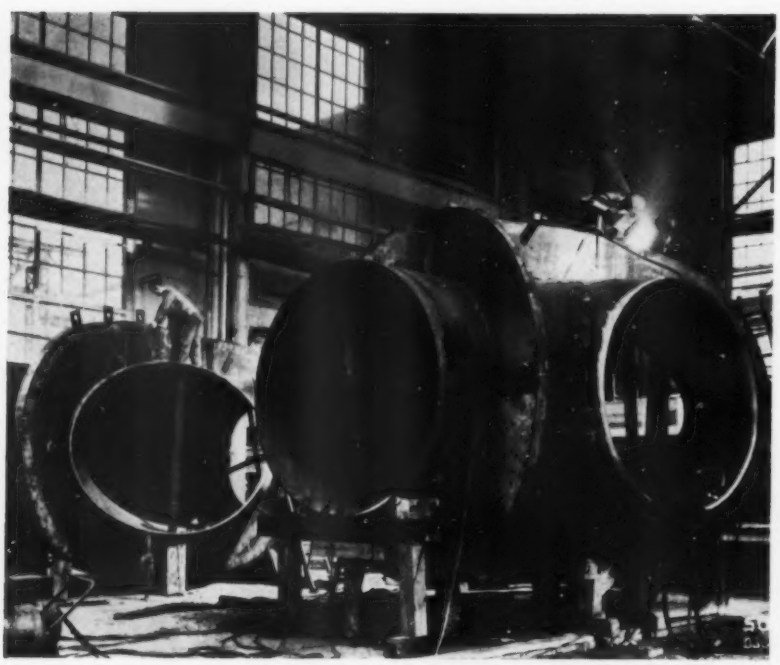
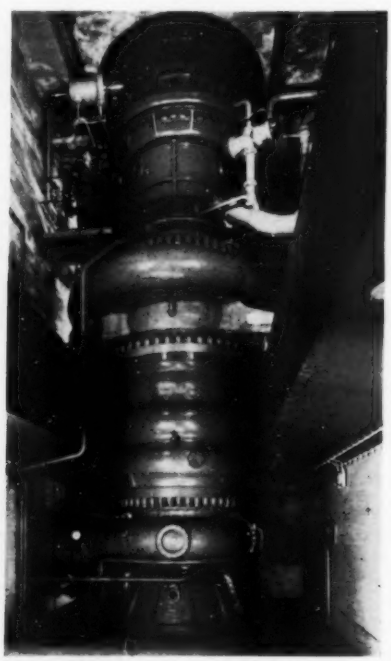


Fabrication of two branch pipes for Ffestiniog in the Sulzer shops at Winterthur. Inside diameter 7 ft. 6 in., service pressure 590 lb. per sq. in.



Sulzer five-stage high-lift pump in an Austrian power storage station. Discharge 49,250 g. p. m., head 3,186 ft., input 55,500 H. P.

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WATER POWER

A technical journal devoted to the study of all aspects of hydro-electric development

"Power Politics" in British Columbia

SOMETHING of a sensation was caused in British Columbia at the beginning of August when the Premier, Mr. W. A. C. Bennett, announced the introduction of a Bill to take over the British Columbia Electric Company from British Columbia Power Corporation and also to acquire the Peace River Power Development Company, in which B.C. Power Corporation has an interest. An offer was also made in the Bill to buy out B.C. Power Corporation itself, and Mr. Bennett indicated that the expropriation of two other private utilities—West Kootenay Power and Light Company, and East Kootenay Power Company—was under consideration. The Bill was forthwith presented to the Legislature and passed unanimously, following which the B.C. Cabinet appointed a Board of Directors under the chairmanship of Dr. Gordon Shrum, the present head of the B.C. Energy Board.

The Government's financial proposals were to purchase the common shares of B.C. Electric from the B.C. Power Corporation at a cost of $111 million, and to replace the B.C. Electric preferred shares with an issue of special bonds at a cost of $104 million. It would also assume the B.C. Electric debt of $399 million. Since B.C. Electric is the principal subsidiary of the B.C. Power Corporation—and the main revenue producer—the Government has also offered to buy out the B.C. Power Corporation at $38·00 per share for its 4·7 million shares, at a cost of $178 million, less the $111 million offered for the common shares of B.C. Electric. Thus the total cost of the take-over would be $682 million, which would double the indirect debt of the Province.

Soon after the take-over, the Government handed a cheque for $111 million to the B.C. Power Corporation to reimburse it for the B.C. Electric Common shares; subsequently the Government floated a $100 million issue of parity development bonds, which was oversubscribed as soon as the offer was made. The new perpetual bonds proposed to replace the B.C. Electric preferred shares have aroused some criticism on the part of investment dealers on the grounds that they will cease to carry the 20% tax credit applicable to the former shares, that they have no call date, and that there is no guarantee that they will be redeemed at par. At the moment of writing, the B.C. Power Corporation have not yet indicated whether they will wind up operations.

Part of the sensation arose from the fact that the present Government is right-wing, whereas for years a B.C. Electric take-over has been the main plank of the party programme of the Socialist Opposition. One of the reasons for the Bill, of course, may have been to remove this plank from the Opposition's platform; but in any case this accounts for the unanimous vote —with the Government and the Opposition each claiming a victory!

One reason cited by the Premier for the take-over was to obtain tax relief from the Federal Government, and thus to relieve a situation with which Mr. Bennett has declared himself to be dissatisfied. Private power companies pay income tax to the Federal Government whereas public power companies do not.

A vital factor in the situation was evidently the recently concluded Columbia-River treaty between Canada and the United States, recorded in our March issue. It is an open secret that the British Columbia Government favoured the development of the Peace River, and the Act just passed will further that aim. Indeed, Mr. Bennett has stated that the development will be prosecuted "rapidly and vigorously." Impetus to the Government's action will have been given by the finding of the B.C. Energy Board—to which we shall refer more fully in a moment—to the effect that the Peace-River development would not be economic on a basis of private finance.

A related motive of the B.C. Government seems to be its desire to increase its bargaining power with the Federal Government over the development of the Columbia. A Provincially owned Peace-River development would form a powerful bargaining counter for British Columbia. Two thorny problems are at issue—financial arrangements and the question of power exports.

We referred a moment ago to the B.C. Energy

Board. An important factor in the general situation is that this body has now published its Report on its findings regarding the comparison between the Columbia and the Peace-River projects. Briefly, its conclusions are:

(a) Simultaneous construction of the Peace and Columbia projects would be feasible only if power were exported.

(b) Private development of the Peace River would not be economically feasible.

(c) Development of either the Peace River or the Columbia River by a public agency would be economically feasible.

The Report shows two sets of power costs, one assuming a normal load growth—a conservative figure of 6·4% per annum—and another assuming that several large power-using industries would be established in the project area. These figures are given in the accompanying table.

Basic load growth		Load growth with power-intensive industries	
	Mills/kWh		Mills/kWh
Columbia ...	4·40	Columbia ...	4·03
Peace (private)	6·60	Peace (private)	6·42
Peace (public)	4·37	Peace (public)	4·20

Under public financing it appears that the Peace-River project is competitive with Columbia-River development. It should be noted that the figures for the cost of Columbia-River power do not include such cost-reducing factors as $65 million in payments for flood-control benefits in the United States; low-cost power that could be developed in the Kootenay reach of the system; and low-cost financing resulting from Federal-Government participation. If such factors were included, Columbia-River power would be cheaper than indicated by the figures we have quoted.

To those of us fortunate enough to be able to follow the situation in British Columbia without becoming involved in it, the possibilities are intriguing, to say the least of it. The Province is fortunate in the abundance of its potential hydro-electric resources, and we are confident that Canadian statesmanship will work out an enlightened policy of power development.

We cannot conclude this brief survey of the position in British Columbia without expressing our deep regret at the untimely death, at the early age of 55, of Dr. A. E. Grauer, Chairman of B.C. Power Corporation. Dr. Grauer was truly the architect of the Corporation and of its subsidiaries and in him the Province has lost one of her most brilliant sons.

Cruachan Underground Station Contract

THE North of Scotland Hydro-Electric Board have placed the contract for the construction of the Cruachan underground pumped-storage power station of the Loch Awe scheme with Edmund Nuttall, Sons & Co. (London) Ltd. The principal feature will be the underground machinery hall which will be about 350 ft in length and 65 ft in width, with an arch roof about 120 ft above the lowest floor level. As far as practicable the rock, which is granite, will be left exposed where it forms the walls of the machinery hall. Adjacent to the machinery hall, additional accommodation will be provided underground for control and switchgear rooms and also for high-voltage transformers to be housed in two chambers each about 45 ft square and 53 ft in height. A combined ventilating and cable shaft about 1,050 ft in height and 13 ft in diameter will connect the transformer chambers with a substation at the surface near the dam. Two inclined shafts, each 15 ft in diameter and approximately 1,700 ft in length, will connect with the dam at the head of the Cruachan Burn to convey water to and from the power station. The connection between the power station and Loch Awe will be by a tunnel 3,200 ft long and 23 ft in diameter. A surge chamber will be provided close to the power station in this tunnel. The whole of this work involves the excavation of approximately 200,000 cu yards of rock.

The civil-engineering consultants for the Cruachan section of the Awe scheme are James Williamson & Partners, of Glasgow.

Kemano Tunnel Repairs

IT was recently announced by Aluminium Limited that aluminium production was stopped as planned at Kitimat in June of this year in order to drain the Kemano power tunnel for inspection purposes. The shutdown took place on June 19 and, as suspected, a rockfall was found in the tunnel. Repair work, which was estimated to cost approximately $2 million, has been undertaken, and resumption of normal operations at Kitimat and Kemano was expected in the first week in September.

New Zealand's Annual Report

THE annual report for the year ending 31 March, 1961, of the New Zealand Commissioner of Works, contains an interesting dissertation on the Cook Strait cable link. The Commissioner clearly supports the opinion of the Power Planning Committee that the scheme should be adopted, and recommends that it should be put in hand forthwith, in conjunction with the approximately 400 miles of overland transmission line that would be required. Some misgivings about the route that the cable should take are expressed, and it is suggested that there should be a reappraisal of the design of the cable, with a view to improving its ability to resist abrasion and corrosion.

Of the divisional reports contained within the main report, that of the Power Engineering Division will be of paramount interest to hydro engineers, as it describes a considerable variety of interesting work. The main projects in the North Island are centred on the Waikato valley, and in the South Island, the Waitaki valley has been the focal point of hydro development for some three decades now. When the Aratiatia station on the Waikato River is completed —and construction is well advanced—no further developments are contemplated in this area. During the year, the 51-MW Waipapa station was virtually completed, and the Ohakuri station commenced power production in January 1961. Excavation and foundation work for Maraetai II were largely completed. At the Atiamuri station, the installation began of the fourth and final generating unit, which will bring the total capacity to 84 MW.

The main construction work on the Waitaki River

was at Benmore, where the operations were approaching their peak. The diversion of the river was completed and, by the end of the year, about 2¼ million cu yards of the earth dam had been placed. Site work also began on the spillway and power intakes. The penstocks were being designed for construction from precast prestressed-concrete sections, and it is said that they will be among the largest of their type in the world.

Site investigations and surveys were carried out for the 200-MW Aviemore scheme, and in the upper Waitaki valley, which has a potential capacity of some 700 MW. Other investigations continued in the Manapoun area. In the Bay of Plenty, a start was made on the 70-MW Matahina station at the mouth of the Rangitaiki gorge, and investigations continued upstream of Matahina. A 100-MW station on the Motu River is also under consideration, together with other schemes farther upstream.

Transformers for Thailand

THREE power transformers, each rated at 58 MVA and stepping up to 230 kV, have been shipped from the ASEA works in Ludvika, Sweden, to Bangkok, where they are being transported by barges a distance of 250 miles up the River Ping to the Bhumiphol power station. Adherence to the stipulated delivery date was important because transport of this heavy equipment up the river is possible only during the rainy season. The Royal Irrigation Board, Bangkok, has now placed an order with ASEA for 16 step-down transformers to be installed in six substations in various parts of the country. They will range from 13 to 27 MVA and will reduce the voltage from 230 to 69 kV. An article on the Yanhee project appeared in our September 1960 issue.

Czechoslovakia to Undertake Survey in Ghana

A CZECHOSLOVAKIAN firm, Technoexport Foreign Trade Corporation, is reported to be undertaking a survey of the Pra, Offin and Ankobra Rivers in the western region of Ghana to select sites for hydro-electric power stations. If suitable sites are found, the company will design and build the power stations.

Electricity Supply in Rhodesia and Nyasaland

ELECTRICITY output in the Federation of Rhodesia and Nyasaland for the year ended June 30, 1961, was 3,903 GWh, an increase of 6½% over the previous year. Of the total units sent out, 42% were generated at Kariba, 24% in the rest of Southern Rhodesia, 18% in Northern Rhodesia, 15% were imported from Katanga and Mozambique and 1% was generated in Nyasaland. The output of Kariba, where four turbo-generators have now been commissioned, was 1,632 GWh, and of these, 901 GWh were delivered to the Rhodesia Congo Border Power Corporation, 366 GWh to the Southern Rhodesia Electricity Supply Commission, 242 GWh to Salisbury, 28 GWh to Bulawayo, 12 GWh to Lusaka and 7 GWh to the Kariba township. Official forecasts made nearly six years ago estimated that the demand on undertakings to be connected to Kariba would amount to 3,488 GWh in the year ended June 30, 1961. The actual demand on those undertakings in that year was 3,326 GWh. The forecast did not include Lusaka and the Kariba township, both of which have since been connected to Kariba. Including those two undertakings, the demand was 3,384 GWh or only 3% below the estimate.

First Set Commissioned at Tokke I

THE first 100-MW set of the 400-MW Tokke I station was recently started up by the Norwegian Prime Minister. The Tokke scheme, which embraces a large area in the county of Telemark in Southern Norway, was commenced in 1956, and Tokke I is expected to be completed by the end of 1962. Its average annual output is estimated to be 2,130 million kWh.

The whole scheme will comprise five power stations with a total capacity of approximately 1,000 MW. The work will include the construction of 30 dams and over 60 miles of tunnel. The project is partly financed by a World Bank loan, as noted in our February 1961 issue.

Grouting Contracts for Dams

THE Cementation Co. Ltd. has secured a contract to strengthen the Shirawta dam, in India. This brings the total amount of work carried out by the Company for the Tata hydro-electric power-supply system during the past two years to £750,000. Drilling and grouting work has been secured at the new West Barwon dam in Victoria, Australia. In this scheme Cementation is the subcontractor and the authority concerned is the Geelong Waterworks and Sewerage Trust.

Growth of Brazilian Energy Demand

THE 1960 Annual Report of the Brazilian Traction, Light and Power Co. Ltd., whose systems cover the Rio de Janeiro and São Paulo areas, shows that the total sales of electricity increased by approximately 11% over the previous year to a total of 9,363 GWh. Rainfall was slightly above average and so it was possible for the hydro plants to produce 73% of the total output.

At the Cubatão underground station on the São Paulo system, the fifth 65-MW generating unit was installed, and it was expected that the sixth and final set would be commissioned in 1961. Work was also resumed on the 93·5 MW Ponte Coberta project in the Rio system, which had previously been delayed due to shortage of funds. This station will utilise the discharge from the Fontes and Nilo Peçanha plants.

Power Development on the Pasvik

THE Norwegian Government, in a Bill submitted to the Storting (Parliament), has proposed the construction of a power plant on the Pasvik River, which forms part of the 122-mile frontier with the Soviet Union. The plan calls for leasing the state-owned Skogfoss waterfall to A/S Sydvaranger, Kirkenes, Norway's largest iron-ore mining company. Development and construction of the proposed Skogfoss power plant would be undertaken by A/S Sydvaranger and the Varanger Power Company.

Fig. 1. Kurobe dam under construction

Some Recent Japanese Plants

Brief descriptions are given of the Kurobegawa No. 4, Miboro, and Okutadami developments. All three plants provide the head storage for their respective rivers and have underground power stations, but the dams are of the cupola-arch, rockfill, and mass-concrete gravity types respectively

By Professor FUMIKI KITO*

THE purpose of this article is to present a picture of recent hydro-electric development in Japan, and as very few articles on Japanese projects have so far appeared in this journal the author has thought it better to give brief particulars of three representative large plants now under construction or recently completed rather than to present a detailed account of a single station. Such a detailed account of some Japanese development may be prepared for future publication. The three plants to be considered in this article are Kurobegawa No. 4, Miboro, and Okutadami. Their locations are indicated in the sketch map of central Japan reproduced in Fig. 2, and they have a common feature in that they are all of the underground type.

Kurobegawa No. 4 Plant

The Kurobe River (Kurobegawa) rises on the flank of Mt. Washiwa in the Japanese Northern Alps and flows northwards between the Tateyama and Hakuba ranges to form a delta, just downstream of Aimoto, discharging into the Sea of Japan. From the hydro-electric standpoint it is the most important river in Japan, for over a watercourse of 86 km its average gradient is 1 in 40, and its catchment area of 787 km^2 is fed by the spring melt from mountain snows (see

Fig. 2. Map of Japan showing the locations of the plants described

* Faculty of Engineering, Keio University, Tokyo.

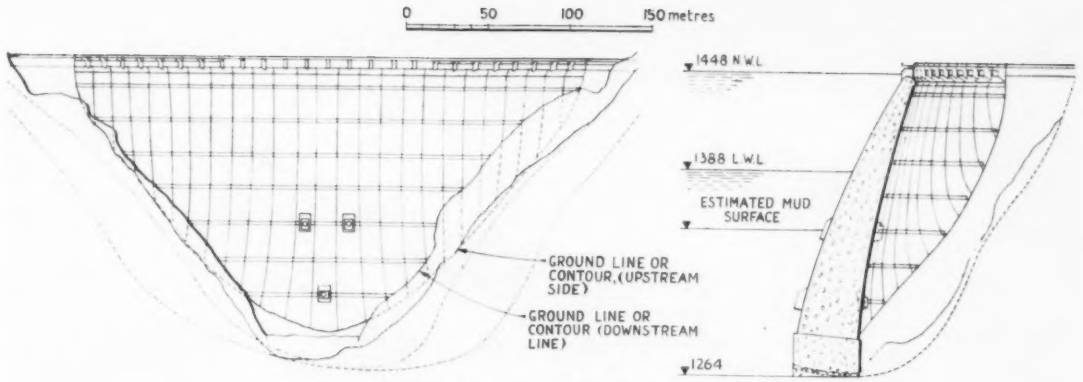

Fig. 3. Elevation and section of Kurobe dam

Fig. 1 for example) which may be as much as 6 m thick.

The Kansai Electric Power Company, who hold the water rights for this river, have already built, over the last 40 years, four stations aggregating 240 MW in capacity on the lower part of the watercourse, but the small amount of storage available reduces the firm capacity of these stations in winter to 60–70 MW. It had long been known that an excellent storage site existed on the upper reaches of the river, but its extreme inaccessibility rendered development costly and physically difficult. Nevertheless, the rapidly increasing demand for power made it essential to build additional capacity, and with the aid of a loan from the World Bank it became justifiable to proceed.

Kurobegawa No. 4 is already partly in operation. When completed it will have an installed capacity of 258 MW, and its live storage of 148·8 million m^3 at an elevation of 1,448·6 m will also provide much-needed winter regulation for the downstream plants, representing a great increase in firm capacity.

The dam site is 55 km from the mouth of the river, and the nearest existing point of access was the railway station at Ohmachi. From this station it is not practicable to get even construction personnel to the dam site by way of the river, and it was necessary to build a heavy-duty mountain road to the site, 26 km in length, 6 km of which is in tunnel. Weather conditions precluded work on the site for more than six months in the year, and aggregate for the dam had to be dug at Ohmachi, carried in dumpers to the mouth of the tunnel, and transported through the tunnel by belt conveyor.

The dam was designed by Electroconsult, Milan, and is being built by Hazama-Gumi K.K. It is a cupola-arch structure, 188 m high, and will be the largest of this type in Japan. It will have a crest length of 447 m, the corresponding chord length being 338 m, and will contain 1,350,000 m^3 of concrete. It will be 10 m thick at crest and 40·2 m thick at the bottom of the foundation collar, and will be a symmetrical structure resting within a circumferential joint. An uncontrolled spillway extends the full width of the crest, and two intermediate discharge sluices and a scour sluice are incorporated in the dam.

The reservoir will be 8·3 km long and 3,489,000 m^2 in area. It will have a total volume of nearly 200 million m^3, of which the useful volume of 148·8 million m^3 is obtained with a drawdown of 60 m.

The intake is located on the right bank and leads to a pressure tunnel 4·8 m in diameter and 10·4 km long. Near the head-valve chamber an inclined surge shaft is taken off about 250 m long and leading to an upper chamber 144·6 m above the centreline of the pressure tunnel. Both the pressure tunnel and the surge shaft are steel lined for a distance of approximately 150 m back from the junction, and a steel

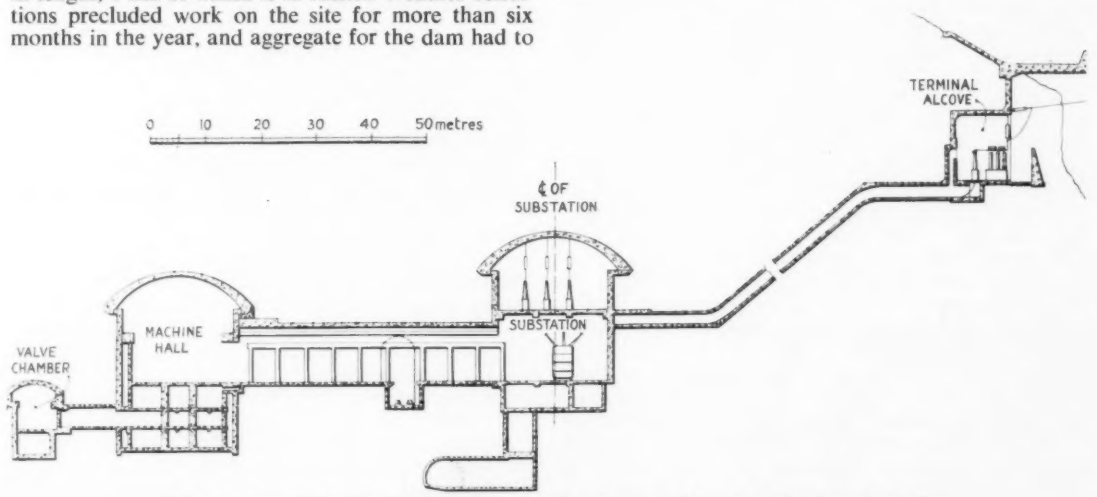

Fig. 4. Longitudinal section through Kurobegawa No. 4 underground station

Fig. 5. Miboro rockfill dam under construction

lining was required for a length of 255 m at an intermediate point in the main tunnel.

The penstock is laid freely in an inclined penstock tunnel, and the manufacture, transport and erection of the penstock and valves were supervised by Soc. Cofor, Milan, the construction work at site being carried out by Sakai Ironworks. A Calzoni butterfly valve is installed in the head-valve chamber, and leads to a Bouchayer & Viallet penstock 768·68 m long and having a diameter reducing from 4·80 to 3·25 m. The penstock is of the self-hooped type developed by its makers, having a pipewall ranging from 12 to 24 m thick and hoops from 27 to 46 mm thick. At the anchor blocks a plain pipe is used, with a wall thickness from 24 to 26 mm. At the power station the penstock leads to a manifold feeding three machines. This manifold is formed by three spherical bifurcations made by Terni, having diameters of 5·1, 4·6 and 4·1 m respectively and supplying a 1·6 m branch pipe to each machine. Admission of water to each turbine is controlled by a Riva oil-pressure-operated rotary valve.

A totally underground power-station construction was adopted, partly because snow conditions are too severe for a surface station and partly because the sides of Kurobe gorge are too steep to offer a suitable site. As will be seen from Fig. 4, even the high-voltage circuit breakers are underground and it is believed that in terms of underground excavation Kurobe is one of the largest hydroelectric stations in the world. In addition to the usual galleries and tailrace tunnel there are four major chambers. The penstock manifold and turbine inlet valves are housed in a separate valve chamber 13 m high by 6 m wide, and the machine hall is 33 m high, 22 m wide and 119 m long. A busbar and communication gallery leads to an electrical-equipment hall 31·6 m high by 19 m wide in two floors, the lower floor containing the main transformers and the upper floor the high-voltage switchgear. From this hall an inclined gallery conveys the high-voltage cables to an alcove, 12·6 m high by 10 m wide, where the cables give place to overhead conductors.

The generating sets are vertical-shaft single-runner six-nozzle Pelton wheels driving three-phase generators. Each set is rated at 90 MW at 60 c.p.s. when running at 360 r.p.m., and at 87 MW at 50 c.p.s. when running at 300 r.p.m. Machines Nos. 1 and 2 comprise Voith turbines driving Toshiba generators, and in the case of the third machine both the turbine and the generator were built by Hitachi. The main transformers, circuit breakers and switching-station equipment were supplied by Toshiba Electric Company (Tokyo Shibaura Electrical Co. Ltd.).

Miboro Plant

The Miboro development (Fig. 6), which is now coming into service, is situated on the upper reaches of the Sho River in the Hida Mountains. Like Kurobegawa No. 4, it is the uppermost of a chain of plants, and its storage capacity will greatly augment the output throughout the watercourse. Miboro has an installed capacity of 215 MW and a live storage of 330 million m^3, and in an average year is expected to generate 610 GWh. There are seven plants downstream, aggregating 300 MW, and with the improved regulation afforded by Miboro they will contribute 280 GWh.

Miboro dam (Fig. 5) is the first rockfill structure in Japan, and is one of the largest dams of this type in the world. It is 131 m high, 405 m long, and 7·95 million m^3 in volume. Rockfill was chosen for

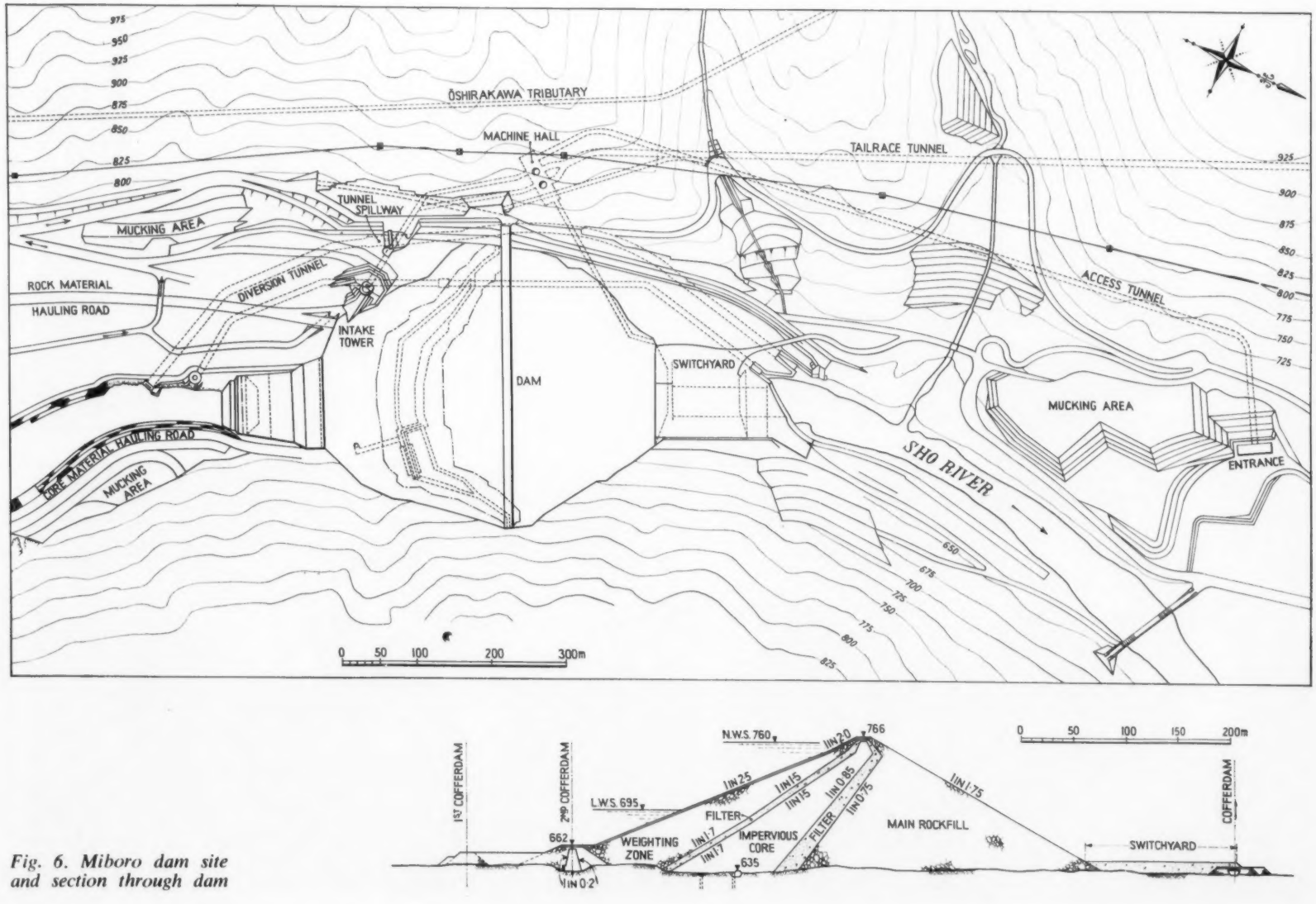

Fig. 6. Miboro dam site and section through dam

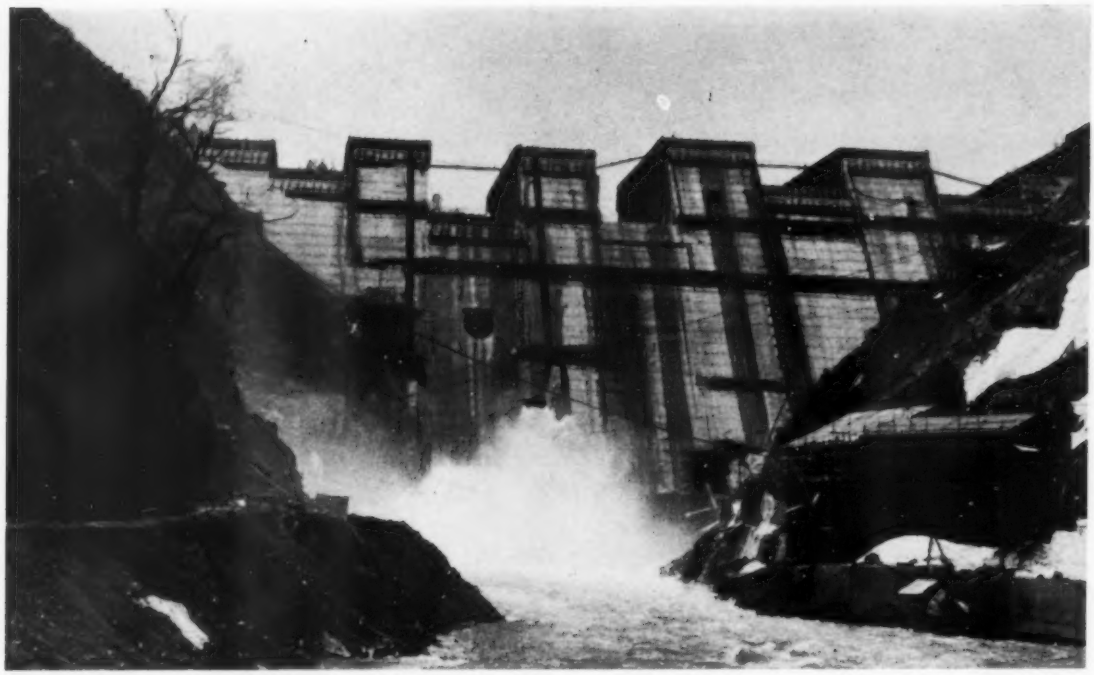

Fig. 7. Okutadami dam under construction

Fig. 8. One of the Okutadami runners

two reasons. In the first place the local rock is granite and quartz porphyry of excellent quality and very suitable as a filling material; secondly, on the right bank at the dam site there is a major fault, 30 m wide, running parallel to the river, which made the site unsuitable as a foundation for a concrete dam. This fault was plugged by sinking a 70 m shaft from which horizontal galleries were driven at three levels. From these tunnels about 18,000 m of holes were drilled and over 1,000 tons of grout injected.

The dam itself, which was built by Hazama-Gumi K.K., has a sloping core consisting of a local clay which was mixed with decomposed granite to reduce its water content to a suitable value. Flood control is effected by the diversion tunnel, which can handle 2,000 m^3/sec, assisted by a surface channel handling 1,000 m^3/sec.

The penstock, which runs free in tunnel, was built

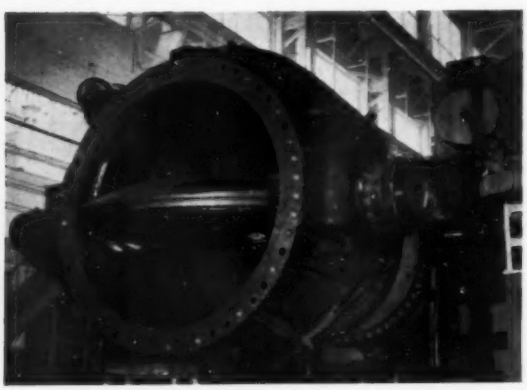

Fig. 9. Main turbine valve in works

Fig. 10. A view inside Okutadami underground power station during the installation of the generators

by Shin-Mitsubishi Heavy Industries, and consists of a single pipe 6 m in diameter for a length of 127 m, after which it divides into two pipes in separate tunnels, each pipe being 4 m in diameter and 226 m long. The wall thicknesses range from 23 to 45 mm.

The machine hall, which is in the left bank, is 90 m below ground and is 42·8 m high, 22·5 m wide and 78 m long. It was constructed by Sato-Kogyo K.K.

It houses two Hitachi 117 MW generating sets, each consisting of a vertical Francis turbine operating under a head of 180 m and coupled to a 60 c.p.s. alternator. The transformers and control room were also supplied by Hitachi Limited, and the circuit breakers in the outdoor switchyard by Toshiba Electric Company.

Okutadami Plant

The Okutadami development*, which is now in service, is situated on the upper reaches of the Tadami River, which originates in Lake Ozehara and is a tributary of the Agano River. The total potential capacity of the Agano River system is estimated at 3,000 MW, which is 10% of Japan's total hydro potential.

Okutadami provides a storage of 458 million m^3 and has a plant capacity of 360 MW. About 15 km downstream is a second station, Tagokura, which has a storage of 370 million m^3 and will eventually have an installed capacity of 380 MW. These two plants will regulate the supply to 11 stations, aggregating 500 MW, on the lower reaches of the river, besides providing water for irrigation. Okutadami will generate 534 GWh per annum and Tagokura 580 GWh; together, the two plants will confer a benefit of 250 GWh per annum on the downstream plants.

Okutadami dam is of the straight gravity type and is 157 m high and 475 m long. It was built by Kashima-Kensetsu K.K.

The adoption of an underground power station avoided difficulties arising from heavy snow (reaching 8 m in depth), and enabled the pressure tunnel and penstock to be shortened, dispensing with an upstream surge chamber. A surge chamber is provided on the downstream side of the station at the commencement of a free-flow tailrace tunnel 2·9 km long. The power station was constructed by Taisei-Kensetsu K.K.

The penstock, supplied by Ishikawajima Heavy Industries Company, has a diameter ranging from 4·3 to 4·0 m and is 221 m long.

Three vertical Francis generating sets are installed, each rated at 120 MW and running at 200 r.p.m. under a head of 170 m. The turbines, valves, generators, control room and transformers were built by Toshiba Electric Company and the circuit breakers by Mitsubishi Electric Company.

Acknowledgments

The author wishes to express his sincere thanks to Kansai Electric Power Company and The Electric Power Development Company for information without which this article could not have been written.

* A full description of the Okutadami development will be published in a later issue.—EDITOR.

Comparative Turbine Model Tests

The author stresses the need for comparative tests on the same test stand in order to predict with accuracy the performance of a machine before it is built

By G. ZIEGLER*

IN general practice, the efficiency and output of water turbines are checked by means of plant-acceptance tests with a measuring tolerance of 1·5–2·0%. After a certain period of operation, turbines may also be inspected for possible cavitation erosion.

In large power plants a difference in efficiency of 2% may well reach a value comparable to turbine price when capitalised. It therefore seems desirable to know the qualities of a turbine beforehand and to the highest possible accuracy. Such information is of particular interest when offers for turbines of different make have to be compared. Model tests carried out in the early project stage can provide all the necessary data. To obtain full accuracy, models must be of the same size and must be tested under identical test-head, approach, and outlet conditions, and the same evaluating technique has to be used throughout. These are necessary conditions since experience has shown that efficiencies measured on different test stands may differ. Differences are due to scale effects as well as to variations in the approach and outlet flow conditions, and can be of an order that must not be neglected. Considering the variety of present industrial turbine test installations, comparative model tests must in fact be carried out on a common test stand.

During the past years such model tests have been carried out in connection with the planning of very large and medium power plants in Austria, and the preparation and execution of these tests will be briefly described.

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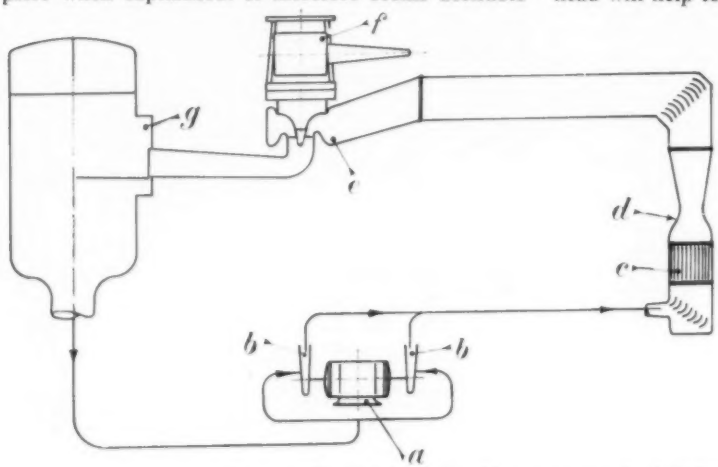
Test Stand

The test stand should be suitable for models similar to the full-size machine from inlet to exit. Simulation of plant cavitation parameters and the possibility for observation of cavitation phenomena are necessary to obtain information on cavitation influences. With respect to model accuracy and Reynolds Number the models should not be too small. A substantial test head will help to increase the Reynolds Number and to avoid air-separation trouble during cavitation tests.



a Variable-speed motor
b Pumps, which may be used in series or in parallel to suit all types of water turbines
c Flow straightener
d Interchangeable set of venturi meters
e Model turbine, 340-mm runner diameter
f 250-h.p. water eddy brake
g Tailwater tank

Fig. 1. Closed-circuit turbine test stand of 400 h.p. capacity

Fig. 1 shows a closed-circuit-type test stand of 400-h.p. pump input. Variation of the cavitation parameter is effected by changing the circuit pressure with pressurised air or vacuum pumps. All readings are taken from a central control board, Fig. 3, immediately evaluated by a machine and recorded on graphs.

Measuring and Calibration Technique

Instrumentation was designed to measure all quantities with an accuracy of 0·1%. Particular consideration was given to calibration devices, and all calibrations are carried out in a way that can be easily controlled to the utmost detail by any observer.

Venturi tubes are used for flow measurement, calibrated *in situ* against a volumetric tank. Head and suction head are measured by means of automatic-reading rotating-piston manometers. Turbine speed is read from an electronic impulse counter, which can be controlled by means of a mechanical counter and a stopwatch over long measuring times. Torque measurement includes friction torque of the bearings and sealings of the turbine as well as the brake (Fig. 2). Weights are used for calibration.

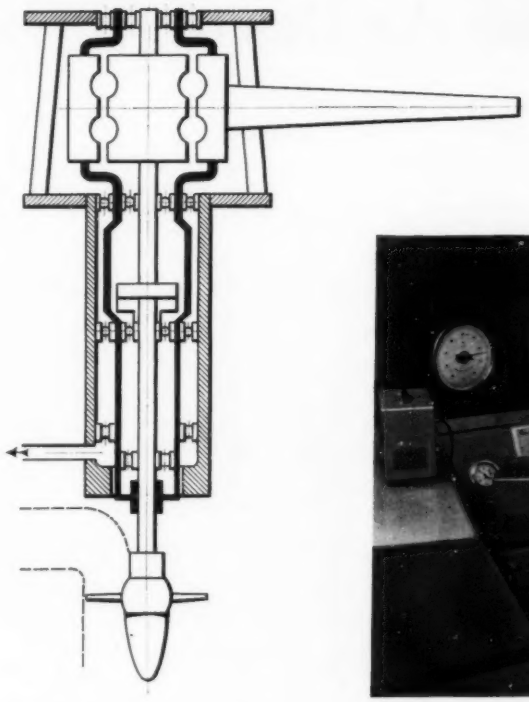


Fig. 2 (left). The special arrangement of the turbine and brake by means of which the friction torque of the rotating bearings and seals is added to the shaft torque

Fig. 3 (below). The central control board at which all readings are taken, evaluated by a machine and recorded on graphs

Preparation and Test Runs

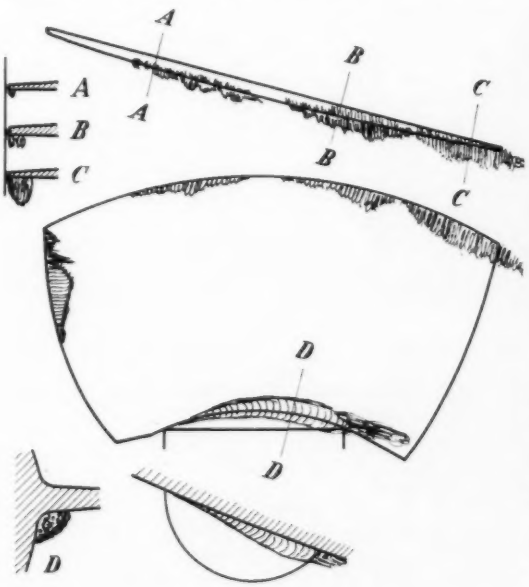
Careful and detailed preparation of a test programme is necessary in advance of the trials in order to ensure quick and correct procedure once the test runs have started.

The power company provides data for head- and tailwater levels as a function of flow. Ranges of plant head and discharge to be covered by model tests, as well as operating conditions for which special cavitation observations are requested, are specified beforehand. On the basis of these hydraulic conditions various working diagrams are prepared to facilitate laboratory measurements.

Depending on the power company's policy, more or less details of plant layout (i.e., speed, diameter, various power-house dimensions) are given or left for the turbine maker to decide. Measuring sections and details of evaluation are laid down.

Before the beginning of measurement the models are controlled for conformity with the above specifica-

(Continued on page 390)



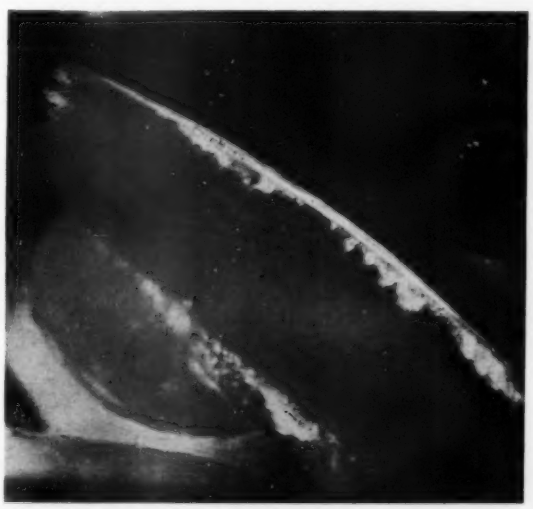


Fig. 4. A sketch and a photograph demonstrating the formation of cavitation phenomena liable to lead to erosion

Water Power for the Desert

In arid regions pumped-storage or pumped-"unstorage" plants would ideally supplement such primary sources as wind, solar and geothermal power

By GEORGE A. WHETSTONE, Ph.D.*

DESERTS present a harsh challenge to the power engineer. The transportation into them of electricity or fuel is usually difficult and expensive. The provision of boiler water of good quality in adequate amounts may be impossible. The generation of solar or wind power is burdened with the necessity of providing standby facilities for darkness or calm. Here again, then, water power may be an important element in a rational development.

Plants on Perennial Streams

It is particularly convenient, of course, to dam a Colorado or a Nile. The value of the water for irrigation and other purposes enhances the economic justification of a project, and the problems of conflicting land uses and of rights-of-way are usually much less onerous here than in populous humid regions with their pattern or smaller more-highly-developed land holdings. In some cases, as where a stream may be flowing between parallel mountain ranges, diversion to arid leeward slopes may be desirable, especially if abrupt power drops could be included in the project. Here also, multiple-purpose development may provide the financial feasibility.

Even the most optimistic retrainer of rivers will admit, however, that few desert areas can ever possess enough major streams flowing across them from well-watered catchments.

Artesian and Geothermal Power

Power in small quantities has been developed in many parts of the world by capping artesian wells and utilising their pressure. Such installations functioned in the London basin in 1840[15], at several localities in the United States in the late nineteenth century[33], and one was reported in Algeria a few years ago[1]. Savornin[19] proposed the irrigation of portions of the eastern Sahara by tapping a 70°C aquifer at about 1,000 m and pumping 26°C water from about 160 m to create a 45°C mixture, ideal for irrigation. Both the mechanical and thermal energies of the 70°C artesian water were to have been utilised.

In general, warm springs are unattractive from the standpoint of thermodynamic output[6]. Where they exist, however, it is often feasible to drill wells which will intercept their supply in the form of steam. The coal equivalent of the geothermal gradient has been computed[4] for France to be as shown in the Table opposite.

The same authorities estimate the actual coal existing in France to average 0·02 tons per square metre of surface. Experiences with geothermal power in Italy, New Zealand, and California indicate that this will be an energy source of increasing importance as the economic balance shifts from competing fuels, as population pressures force further encroachments into arid zones, and as technological advances reduce the cost and difficulty of deep drilling and of corrosion protection. It is at least highly plausible that in many geothermal installations—as in atomic and traditional thermal plants—system economy will dictate a constant rate of generation with the peaks of the demand curve being being served by pumped-storage hydro.

Wind Power

Wind power has received increasing attention in recent years[9, 20-27]. Acceptable solutions to the technical problems of wind turbines exist, and commercial operation in many of the world's most favourable sites is imminent.

As a source of energy wind has been shown to be trustworthy; as a source of power it is unreliable. The major problem in its use, then, is to provide standby plant with stored energy. For small isolated installations this may take the form of storage batteries. On a larger scale, study has been given to energy-storage in a heated liquid in an insulated container, and to the hydrolysis of water with storage of the hydrogen. The method of energy conversion most apt to appeal to a hydraulic engineer, however, is one that closely parallels the functioning of the familiar rural windmill—the pumping of ground water to an elevated tank.

Two possible programmes suggest themselves for accomplishing this operation:

(a) All water might be pumped to an upper reservoir by means of a purely mechanical connection between wind-wheel and pump. Generation of electricity would then be obtained by operation of a hydro-electric plant in the conventional manner.

(b) By a complex of switching gear an aero-generator could be scheduled to carry such part of the base load as it could handle with a pumped-storage hydro-plant maintaining balance between supply and demand.

The choice to be made between these programmes at any given site would depend on several considerations. In general, solution (b) would be acceptable

Depth in metres	Coal equivalent in metric tons per square metre of surface
2,000	0·246
4,000	1·83
6,000	5·61
8,000	12·1

* Professor of Civil Engineering, Texas Technological College.

only if the plants in question were interconnected in a larger grid so that the hydro plant could be set to generate as needed on a predicted peak in the power demand, and then set to pump as excess power became available at other times of day or season. A situation in which it "hunted" due to a gusty wind would be intolerable. Perhaps, under some circumstances, twin hydro plants—one set to pump, the other to generate—would be desirable. The appeal of solution (a) lies in its simplicity. The additional cost of the separate penstock would be offset to some extent by the elimination of electrical equipment at the windmill and of the switching devices.

Solar Power

Nearly a century ago Mouchot[16] predicted that solar power plants would be employed in deserts. In many papers throughout the 1870's he reported progress with experiments in Algeria and success in tests of cooking, distilling, and of the production of power. Contemporary surveys often conclude that we, too, have reached the threshhold of an industrial breakthrough. Cost figures based on current equipment indicate that only in the fields of space and water heating is this the case. Power production, in commercially interesting quantities, still requires too large a capital investment to be competitive.

Sooner or later, however, rising power demands coupled with exhaustion of fossil fuels on one hand, and further research in solar-energy utilisation on the other, will lead inexorably to the harnessing of the sun. This development, since the characteristics of wind power and solar power are alike in their rigid adherence to timings of their own choice, will almost inevitably entrain the use of hydro-electric auxiliary plants on one or the other of the programmes already discussed.

Pumped Storage

Recent studies[11, 12, 13, 35], which have in no way limited themselves to applicability to arid regions, have disclosed a growing conviction that water power's most important contribution is to be found increasingly in its flexibility. As a consequence of this philosophy pumped storage will assume a role of increasing importance. In humid regions, and along favoured stretches of rivers flowing through deserts, pumped-storage operation can be expected generally to be associated with natural inflow to the upper reservoir and with water releases from the lower reservoir[31]. With rare exceptions—and the Atacama Desert of northern Chile with its 0·04 in of rain per year seems not to be one of them[17, 18]—a two-basin pumping installation could be depended upon to temper the obdurate march of thermal plants on the one hand, and to salvage the random spurts of wind and sun on the other, to meet the demand.

Make-up water would normally be ground water, which might be obtainable from the *foggaras* of the Sahara or from prosaic wells. Often auxiliary problems of evaporation control[32], seepage control, and ground-water recharge[3, 28, 34] would require attention. Heavy silt loads are a concomitant of aridity.

Hydro-Solar Power

A fascinating application of hydro-electric principles is that in which the ocean replaces the upper reservoir and evaporation is depended upon to maintain head by removing water from the tail pond. This still awaits its first practical test.

Since WATER POWER published "La Houille d'Or"[30] in 1954, Vadot[29] and Le Grain[14] have made significant contributions to the study of hydro-solar power plants. Vadot focused attention on the differences inherent in a "marine" plant such as that proposed at Lake Maracaibo[7] and a plant "of depression" such as at Lac Assal. A marine scheme is defined to be one in which the head results from the blocking of a bay or cove, followed by its evaporation; a depression scheme is one in which sea water is led to a pre-existing depression dipping to well below sea level. Recognising the major disadvantage of the marine plant to be the delay of several years involved in waiting, after closure, for evaporation to reduce the head to the desired value, he proposed a system of temporary closure by an inexpensive float-supported impermeable curtain. Following his plan the dam would be built as needed in harmony with the slowly increasing head. Use of the power plant could be permitted at a reduced rate before the final level was attained, but such use would, of course, delay the attainment.

Here, again, it would appear that a combination with tidal, thermal or wind generation or with a run-of-river power source having moderate transmission distances might well prove its value. The use of dump power for pumping from tailwater, particularly in the early years when the head differences were only a few feet, would shorten the period of frozen capital (if one may use such a term in speaking of the Somali Coast, Arabia, Mexico, or Western Australia). Moreover, with an auxiliary power source the use of the hydro-solar basin for development of peaking power would be economically attractive at a date much earlier than that of the final design level. The water pumped might well be evaporated elsewhere for recovery of its chemicals.

Even with an auxiliary power supply obtrusively present, it would be more difficult to justify the use of "pumped unstorage" with a depression plant, at least in the early years when excessive storage space was available and when the load had not attained a maximum. Later, however, with the investment in the original plant repaid, with a growing demand in view, and with the point of diminishing returns of a pure hydro-solar installation reached, pumping from tailwater might again be considered in connection with any new power source added, especially as the peaking capacity of the hydro-solar plant is a linear function of the head available.

If further emphasis were needed on the thesis that water power is adaptable to even the most exotic schemes in hydraulic engineering, Kervran has supplied it in his proposed revision of Roudaire's project for the flooding of the Chott Melrhir[2, 36]. Discarding Roudaire's basic premise that an inland sea in the Sahara would lead to increased rain and other modifications of the climate of Algeria and Tunis, he has revivified this scheme which inspired Jules Verne's "L'Invasion de la Mer," by advocating it as a means of developing 500 million kWh/year from a 20-m fall with the tailwater being destined to irrigate pastures of salt-tolerant forage before its ultimate evaporation.

While conceding that dairy products from such a source are "sans valeur commerciale car d'odeur trop forte," he praised the "chair savoureuse" of such beef and indicated that sheep were even more tolerant

to salt than are cattle; camels, it seems, thrive on weeds that would be repugnant to sheep.

Summary

Water power is applicable to desert conditions in providing the flexibility, by means of pumped-storage plants operating on ground water, to supplement such primary sources as wind, solar or geothermal power.

In desert areas where they exist, bays or inland depressions may furnish large blocks of power for irrigation, electrochemical processing of sea water, and other purposes. Here "pumped unstorage" from the tailwater by surplus tidal or run-of-river power may enhance the financial attractiveness.

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tions. Equality of measuring sections and clearances is also checked. All measuring devices are calibrated, and calibrations and main tests are carried out in the presence of any observers requesting to see them.

Repetition and scatter of calibrations as well as of efficiency measurements provide information on the reliability of comparative tests. Kaplan-turbine propeller-efficiency curves have been reproduced within 0·1–0·2% repeatedly, and on some occasions after dismantling and remounting of the model turbine.

Test Results and Conclusions

Model efficiencies are plotted in the form of oak-leaf diagrams; these are the basis for the integration of the annual generation. It is, of course, also possible to integrate the product of output and power cost for the average year.

Detailed drawings of cavitation phenomena are given for all operating conditions, Fig. 4. As a general rule, drawings are superior to photographs, since pulsation of cavitation, irregularities of model runners, differences of observation window design or camera position may lead to wrong conclusions.

Comparative model tests carried out in the project stage of hydro-power plants provide information concerning the hydraulic qualities of different turbines before the plant is built and at an accuracy not available otherwise.

Systematic tests of this kind carried out alongside with plant-acceptance tests and observation of plant corrosion will help to improve present knowledge on scale effects as well as on the relation between visible model cavitation and plant corrosion. By this improved knowledge the model test will also become a means for the absolute prediction of full-size turbine behaviour.

Rock Mechanics and Hydro-Power Engineering

The author presents a case for a more scientific approach to Rock Mechanics, and hopes as a result to stimulate more systematic research work. In this final article, he considers the part played by grouting in the application of Rock Mechanics to dam foundations and pressure tunnels

By DR. CHARLES JAEGER*

PART TWO

Grouting of Rock from Tunnels

Grouting of rock from tunnels is used for many purposes, for example:

(a) To stop water leakage from a pressure tunnel into the rock fissures.
(b) To stop water under pressure in rock fissures penetrating into the pressure tunnel when the natural water pressure u in the rock is higher than the pressure p in the tunnel, or when emptying the tunnel.
(c) To consolidate the rock.
(d) To stress or prestress the tunnel lining, and to consolidate it.

Experience has shown that all four purposes can be achieved successfully with rock grouting. Many examples of success can be mentioned, and also a few failures, but little effort has been made to analyse the actual mechanical process that occurs in rock fissures and seams during the grouting.

The following is a tentative interpretation of what may happen in a fissured rock when grouted. The grout pressure p' is assumed to be higher than the water pressure u in the rock fissure. When settling in the fissures, the water passages are plugged and the amount of water circulating in the passages is greatly decreased. Increased friction losses in the passages still open also reduce the water discharge.

Assuming the stresses in the dry rock to be σ and τ, rock is stable (Coulomb) when

$$\tau < C + \sigma \tan \phi.$$

In wet rock fissures the uplift pressure u causes a drop in the rock strength, as

$$\tau < C + (\sigma - u) \tan \phi$$

is now the stability condition (Figs. 22a, b, and c).

Internal rock stability is restored when $p' = u$, where p' is the grout pressure after settling of the cement grout. For $p' > u$, a certain amount of rock prestressing may help to consolidate the rock (Figs. 22b and c) as now

$$\tau \leqq C + (\sigma + p' - u) \tan \phi$$

is the limiting condition for internal rock stability.

This interpretation may be over-optimistic because of the shrinkage of the cement grout in the rock fissures, and because pore pressure in rock pores and in the fissures—as opposed to water pressure in the rock seams—can hardly be suppressed by grouting.

In spite of these reasons for discouraging too great an optimism about rock grouting, it has been proved by experience that rock can be plugged by grouting, fissures can be dried out, rock can be consolidated, the rock modulus of elasticity can be improved in many cases (not in clayish type of rock), and tunnel linings can be prestressed.

In contrast to dam abutment or foundation grouting (when the efficiency of grouting cannot be checked), the efficiency of tunnel grouting can to some extent be checked from inside the tunnels. Positive results obtained by tunnel grouting must be kept in mind when discussing dam foundation grouting.

Drainage of Tunnels

Small drainage pipes, parallel to the tunnel, are unreliable since they may be plugged by grouting. Only a few may survive (Ober-Aare tunnel). Larger drainage galleries, parallel to the pressure tunnels, are dangerous because of over-stressing of the lining of the pressure tunnel (accident to Gerlos tunnel).

It is recommended that the rock should be drained in a direction more or less perpendicular to the pressure tunnel (e.g., Kemano, Gondo, see Fig. 23), using to the utmost adit galleries and boreholes drilled from these galleries towards rock seams suspected of being water-bearing.

Rock Uplift Caused by Grouting Around Tunnels

A tunnel with a diameter $2R$ is grouted, the borehole length being l on each side of the tunnel. Grout penetrates to a certain depth in the rock. $D' > 2R + 2l$ is an estimated width of the area on which uniform grout pressure p' is supposed to be applied. If, in the worst case, the rock is fissured (Figs. 24 and 25), there is a tendency for the rock to be lifted. The extended theory of Boussinesq can be used for the analysis of rock stresses.

According to Fig. 26, a pressure p' uniformly distributed on a width D' causes at point O', at a distance z from O, a vertical stress $\left(z = \frac{D}{2} \tan \alpha\right)$

$$\sigma_1 = \frac{p'}{\pi} (2\alpha + \sin 2\alpha)$$

Using the extension

$$\sin x = x - \frac{x^3}{3} + \ldots$$

* Civil-Engineering Consultant to The English Electric Co. Ltd.

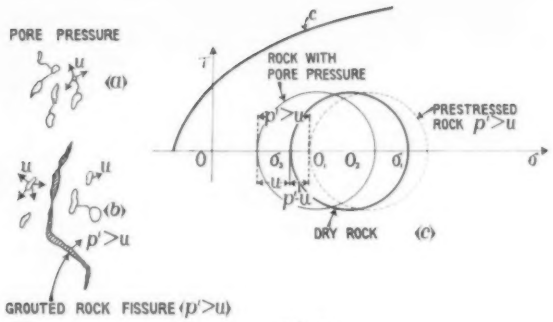


FIG. 22

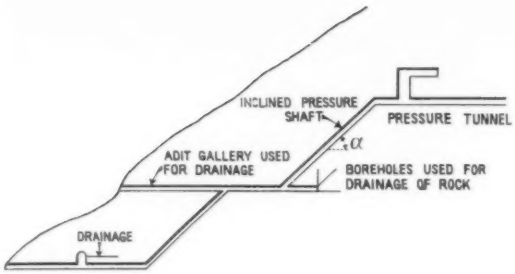


FIG. 23

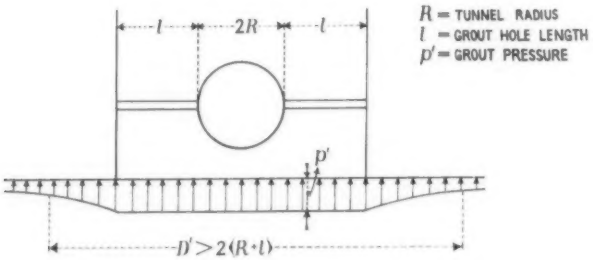


FIG. 24

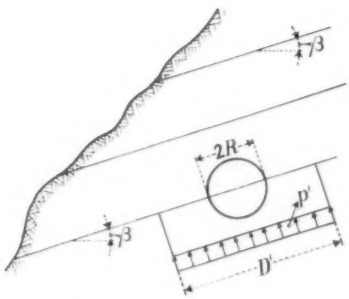


FIG. 25

$$\sigma_1 = \frac{p'}{\pi}\ 2\ a\left[1 + 1 - \frac{(2\ a)^2}{3} + \ldots\right] \cong \frac{4\ a\ p'}{\pi}\left(1 - \frac{2}{3}\ a^2\right)$$

In order to avoid uplift, the condition

$$\sigma_1 < w_2\ (H - Z)$$

must be satisfied or

$$\frac{p'}{w_2\ (H - Z)} = \lambda^* < \frac{\pi}{4\ a\left(1 - \frac{2}{3}\ a^2\right)}$$

On the other hand

$$\tan\ a = \frac{D'}{2\ Z} = a\left(1 + \frac{a^2}{3} + \ldots\right)$$

Combining the last two equations yields:

$$\frac{p'}{w_2\ (H - Z)} = \lambda^* < \frac{2\ \pi\ Z}{4\ D'}\ \frac{(1 + a^2/3)}{(1 - 2\ a^2/3)}$$

or

$$\frac{p'}{w_a\ (H - Z)} < \frac{\pi\ Z}{2\ D'}\ (1 + a^2) = \frac{\pi}{2}\left(\frac{Z}{D'} + \frac{D'}{4\ Z}\right)$$

Assuming z to be small compared to H, this third-degree equation can be transformed into a simpler one of the second degree, which is sufficiently accurate for the present purpose, by writing $1/(H - z) \cong (H + z)$ and finally

$$Z^2\left(1 - 2\ \frac{p'}{w_r}\ \frac{D'}{\pi}\right) - 2\ Z\ \frac{p'\ H\ D'}{w_r\ \pi} + \frac{D'^2}{4} \geq 0$$

which yields Z, the distance from 0 at which the vertical stresses σ_1 tending to lift the rock are less than the downward stresses caused by the weight of the overburden.

A similar calculation should be carried out for horizontal stresses so that

$$\sigma_h < k\ w_r\ H$$

and the occurrence of vertical fissures is prevented.

According to Fig. 25, a similar calculation can be repeated in any direction, at any angle β that might be considered dangerous.

Dam Abutment Stability. The Oblique Sections

Dam designers only too often stop their investigations in the immediate vicinity of the dam abutments. Horizontal arches (Fig. 27) or vertical cantilevers (Fig. 28) are analysed. The resulting force R from arch thrust or dam reaction is supposed to be transmitted to a more or less homogeneous resistant elastic rock, and rock stresses in the immediate vicinity of the abutment are ascertained on this basis.

Let us now consider, in Fig. 29, any section a–a through a dam, inclined at any angle β to the vertical ($\beta = 0$ or $\beta = 90°$ being just special cases of the more general one considered here). The analysis of such a section is entirely justified by the fact that, according to the modern theory of plunging arches, the direction of the principal stresses at a depth h is likely to be more or less perpendicular to the rock surface. The rock, which may be fissured or plastic, pervious or not pervious, is now part of the abutment to be analysed for its stability.

As seen on Figs. 29a and 29b, in addition to the force R_1 which is the reaction of the "plunging arch" on the rock abutment, a load R_2 may have to be considered which represents the hydrostatic load on the rock bottom near section a–a. At the crown of the dam, taking $\beta = 90°$, R_2 does not exist. At the bottom of the valley, with $\beta = 0°$, the force R_2 may be more or less parallel to R_1, but now depends on $H =$ dam height. At greater depth the force R_2 may reach values sufficient to incline unfavourably the resultant

$$\vec{R^*} = \vec{R_1} + \vec{R_2}$$

On Fig. 29a, two lateral forces S_i, S_{i+1} are indicated.

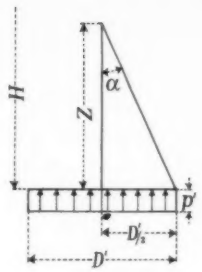


FIG. 26

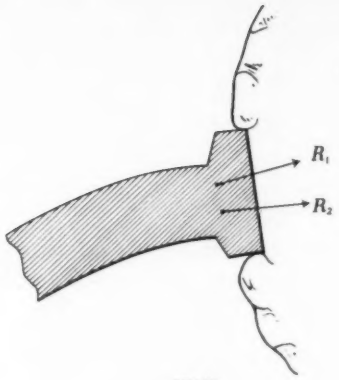


FIG. 27

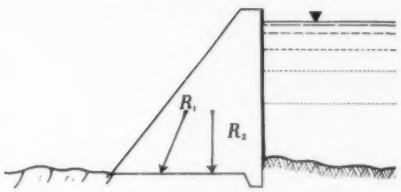
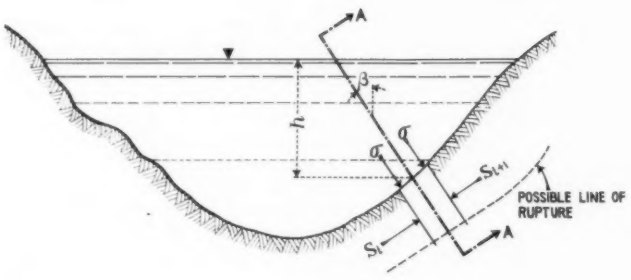
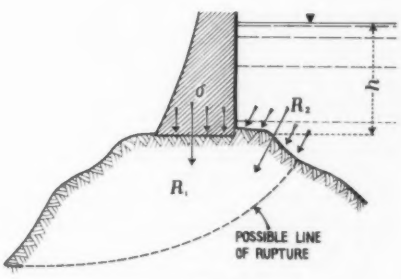


FIG. 28



(a)



SECTION A.A.
(b)

FIG. 29

It seems that they "anchor" the block of rock laterally. This would be true only if the neighbouring rock were really much more stable than the rock under consideration. It is well known that for ordinary dam-stability calculations such forces are neglected in the first approximation.*

It is suggested that the stability of the shaded mass of rock can be analysed in first approximation with methods similar to those used in Soil Mechanics for analysing rockfill or earth dams. A line of minimum resistance in rock has to be found, using a trial-and-error approach. Deeper in rock the length of the line increases rapidly and stability is assured.

Alternatively, rock may be weakened by existing seams and fissured strata (Fig. 30), especially if water in the seams causes uplift pressures (Fig. 29 can be taken as an oblique section at any angle β).

When rock abutment stability is being analysed, the internal cohesion of rock has to be estimated and τ values, where $\tau \leq C + (\sigma - u) \tan \phi$, should be introduced in the calculation.

Systematical analysis of stresses near the abutments of dams on three-dimensional models should be used more frequently. These test results will have to be compared with rock tests made in preferential directions (prestressed cables).

Rock Grouting versus Rock Drainage for Dam Foundations

Very recently Professor A. Casagrande, of Harvard University, USA, delivering the first Rankine Lecture,† discussed the various aspects of seepage under dams. He made a strong case in favour of drainage and against grouting of dam foundations on pervious rock or on alluvium.

He pointed out that uplift pressure under dams decreases from a maximum, more or less equal to the water depth in front of the dam. The decrease is mainly linear up to the point where the drainage gallery collects water from the drainage wells (Fig. 31); it then joins, more or less linearly, the downstream water level. It can be shown that the line of pressure follows, on the whole, the theoretical pattern of pressure as given by the theory of wells. There is no sharp pressure drop through the grouting screen, as would be expected if the grouting were efficient.

The above are the broad outlines of Casagrande's thesis.

The writer is fully aware of the importance of drainage.‡ The necessity for drainage has been accepted this side of the Atlantic as it is on the other side. In recent years it has been used systematically for relieving water pressure in rock under dams. New drainage techniques have been developed for tunnels, too. At Gondo power station (region of the Simplon on the southern side of the Alps), designed by Swiss consultants, an adit tunnel half-way up the mountain slope was kept open with open drainage holes in the rock, in order to drain fissured rock round a steel-lined pressure shaft. Similarly for many recent designs of underground power stations, the writer

* A similar approach to dam abutment stability has been developed by L. Müller.[*] See also the discussion on Large Dams, reference 42.

† Delivered on January 25, 1961, at the Institution of Civil Engineers, Great George Street, London. The lecture is published at full length in *Géotechnique*, September 1961. The writer apologises for giving here only a rough outline of a long lecture of great weight. See, however, WATER POWER, March 1961, p. 85.

‡ A full chapter has been devoted to drainage problems in reference 21.

recommended that the caverns should be protected against water pressure by systems of horizontal drains driven deep into the rock. Drainage is therefore accepted as a most versatile method of relieving pressure in rock pores and rock fissures. A practical example of general drainage of rock under a dam and round an underground power station is given by R. G. T. Lane and J. W. Roff.[37]

The success of rock drainage, which had been predicted by theoretical investigation, should not obscure some other points of great importance.

It seems to the writer that the interpretation of the words "grouting screen" as used by Prof. Casagrande is misleading. Grouting does not create a thin, nearly impervious screen, causing a sharp pressure drop in rock pores or fissures between its upstream and downstream sides. On the contrary, the grout is supposed to penetrate rock fissures over a wide area "B" (Fig. 32) upstream and downstream of the boreholes and, therefore, even when technically perfect, it will not cause a sharp drop in the pressure line.

A theory was developed some years ago,[21] which can be better applied to grouting screens than the theory of Dachler (given in Fig. 33) as used by Prof. Casagrande in his analysis. Dachler visualises a thin semi-pervious vertical screen underneath the foundations and calculates the theoretical "efficiency" of this screen for reducing the flow of water and causing a pressure drop in the piezometric line along the passage of seeping water. He shows this efficiency to be very low.

The alternative representation consists of describing the grouting screen as creating a barrier of a width B with a seepage factor k_1, substantially smaller than k_2, the seepage factor of the non-grouted rock (Fig. 34). The theory shows that the piezometric line would follow a pattern which is not dissimilar to that obtained by direct pressure measurements under dams. Therefore the measurements made on site cannot be invoked to prove that grouting is useless.

There is one important point in favour of a thesis stating that the efficiency of drainage overshadows the efficiency of grouting for better pressure distribution under dams. (It must be understood that the "drainage curtain" as used in the USA consists of wells of about 3 in diameter, ten or possibly five feet apart, this being a rather dense net of drainage.) It is a fact that measurements have shown the importance of the location in position and elevation of the drainage gallery. As the pattern of measured pressures depends mainly on the position of these galleries, there a proof of the efficiency of drainage is to be found.

Drainage is, therefore, an element of paramount importance in the design of the dam foundation. The pressure line under the dam, and also below the dam foundations, will primarily depend on the drainage system.

On the other hand, grouting has proved to be an efficient method of dealing with natural water pressure in rock around tunnels, galleries, or caverns. There is no reason for a technique that is successful in one case to be a failure in a similar case.

This leads to the question of "What are we after?" What is the result to be expected from rock grouting under the foundations of a dam, and what can we expect from drainage?

The first object of grouting is to reduce the overall rock permeability and therefore the water discharge in rock fissures, which is different from water pressure in pores. The pressure line may be altered only slightly or not at all by rock grouting. A spectacular change in the shape of the pressure line, showing a drop of pressure in rock fissures and in the rock pores, can be better achieved by drainage than by grouting. But drainage does not reduce the discharge. It has a tendency, by causing a sharper pressure gradient, to increase the discharge, which is an obvious danger that may lead to water eroding the fissures in the pervious rock.

To take extreme cases: There is no doubt whatsoever that drainage would have achieved nothing to reduce water seepage at sites like Monte Jaque (Spain), Camarasa (Spain), or Dokan (Iraq). Grouting or similar methods used for sealing fissures and faults were the only possible remedies.

Reducing the discharge of water may be economically of great importance for high-head schemes, where every cubic yard of stored water has a high economic value. But whatever the economics of grouting, the sole question of safety has to be examined here and grouting is found to be, from this aspect, as important as drainage.

The second function of rock grouting, which consists of consolidating the rock and prestressing it, is no less important. This has already been made clear for tunnels. For dam foundations the problem has been dealt with by Talobre in his textbook on Rock Mechanics.[24] For a given rock type and rock quality, rock strength depends on $\sigma_1 - \sigma_3$ ($\sigma_1 > \sigma_3$), where σ_1 is the vertical rock prestressing and $\sigma_3 = k\sigma_1$ ($k \leq 1$), the horizontal rock thrust. When the water pressure in the rock is u, rock cohesion decreases by $u \tan \phi$ ($\tan \phi$ = internal rock friction).

Let us assume the rock foundation to be stable before building the dam. When a dam with a height of H metres or feet is put under pressure, the uplift pressure in rock fissures and pores rises to $u + w\,H$ (w = specific weight of water). The rock cohesion decreases by $w\,H \tan \phi$ and the rock may become unstable.

One of the main objects of rock grouting is to create a permanent residual prestressing of the rock, which offsets the effect of this pore pressure increase. Talobre goes as far as recommending pinning the rock foundations when high pressure grouting is either impossible or not efficient.

Assuming that, according to American practice, the drainage is located at about 50 ft (15 m) downstream of the dam upstream face; all the rock volume between dam face and drainage screen must be consolidated by grouting if a sharp drop in rock strength is to be avoided in the foundation under the dam. Whatever the success of rock grouting in slowing down the seepage and in consolidating the rock, a comprehensive drainage system is compulsory for controlling pore pressure in the dam and under the dam and in rock fissures—pore pressure being considered here rather than pressure in rock fissures. It is possible to agree with Professor Casagrande on the broad lines of his remarks on drainage, but one has to disagree on some other important points concerning the efficiency of grouting.

At the end of his Rankine Lecture, Prof. Casagrande mentioned the difficult problem of the treatment of the foundations of very thin arch dams. There is no doubt whatever that Prof. Casagrande's criticisms have to be taken most seriously. He observes

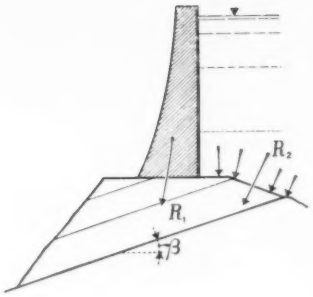


FIG. 30

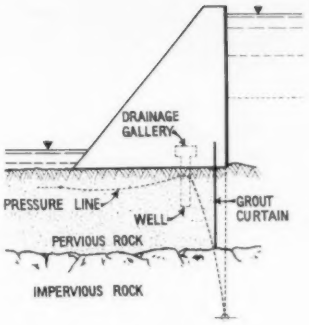


FIG. 31

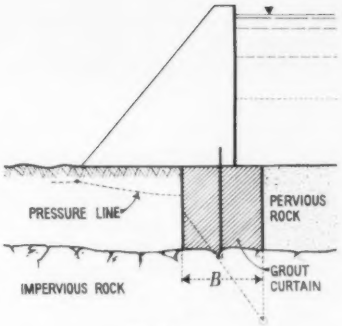


FIG. 32

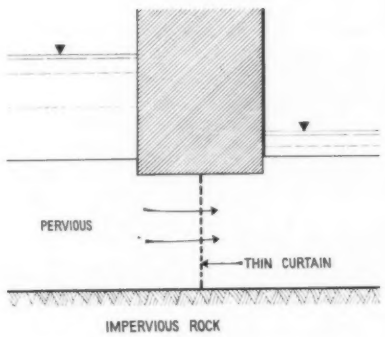


FIG. 33

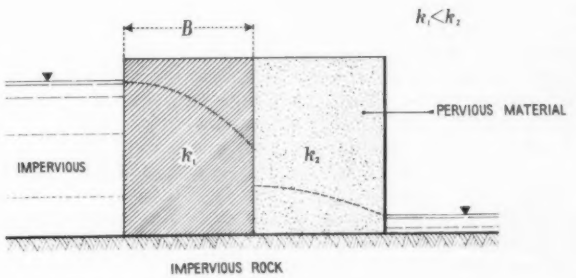


FIG. 34

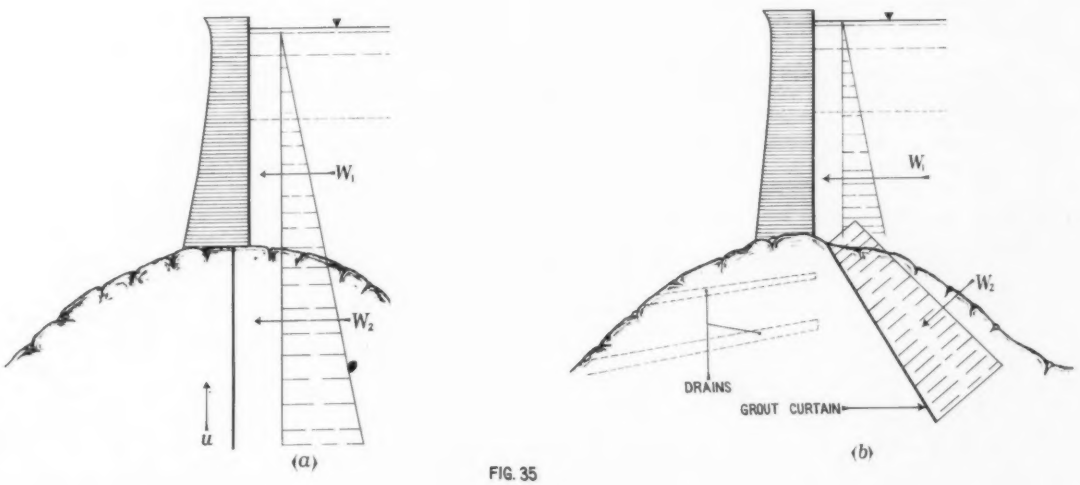


FIG. 35

that, under a thin dam, there is no room for efficient drainage and suggests a widening of the dam abutments. (Could a solution on the lines of the abutment design of Lumiei dam be considered as a general proposal for thin arch dam foundations?)

An alternative solution would be a series of galleries in the rock, downstream of the dam, and horizontal or oblique drainage holes reaching the dam foundations. If the author's belief is correct that "oblique sections" may reveal more dangerous conditions for the dam foundations, then special care should be taken of this area.

This criticism by Prof. Casagrande meets some recent remarks by engineers of Electricité de France. Their point is best shown in Fig. 35a. When an impervious grouting screen is created under a dam, the hydrostatic pressure increases linearly to the full depth of the screen. (This remark is implicitly included in Prof. Casagrande's approach.) The pressure on the foundations may jeopardise the stability of the dam.

The writer suggests in Fig. 35b a tentative answer to this criticism. In this figure the dam section could be an oblique section, similar to Fig. 29. The grout-

ing curtain is shown steeply inclined in the upstream direction and uplift under the dam is relieved by a system of convenient drainage galleries.

Conclusions

This article puts forward some suggestions to show how Rock Mechanics could be used for the purpose of analysing the general stability of tunnels and dam foundations. However, in the opinion of the author, these ideas still include too much guess-work.

For many years there existed an empirical approach to Rock Mechanics; experience was the only teacher. Then came the first attempts to test rock. Rock elasticity and plasticity were introduced into Rock Mechanics, and the new concept of rock prestressing caused great changes in the whole approach to rock stress and strain analysis. A far more precise analysis of the in-situ rock strength became possible.

It is suggested that the present position could be summarised as follows: An effort is being made by several authors to analyse stress distributions in rock, which is assumed to be an isotropic body. Stresses round a tunnel have been dealt with in this article as an easy example. Other important problems (e.g., stresses under a dam) have been solved in recent years and some papers submitted to the Seventh Congress on Large Dams contribute important new material.

Model tests may show how the stress distribution thus obtained is altered when the rock is supposed to be anisotropic, stratified, or fissured. Alternatively, some cases may be solved using digital computers or analogues. Some interesting results have already been obtained by both methods.

On the other hand, techniques for testing rock in situ are being developed or improved. Some new ideas have been submitted here and other methods noted[38, 43].

The two trends will converge: Test results on rock will be compared with theory and will ultimately help to develop a Science of Rock Mechanics. Mohr circles and the "intrinsic curve for rock failure" will probably be important links in this theory.

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The Chemical Control of Water-Weeds

The author draws attention to the fact that water-weeds in reservoirs and channels can pose considerable problems, and discusses various chemical methods of controlling their growth

By ERIC HARDY, F.Z.S.

THE choking of large areas of the new Kariba reservoir with an excessive growth of water plants, in particular *Salvinia auriculata* and *Pistia stratiotes* (the Nile Cabbage), has recently shown the importance of modern research into the control of water-weeds. The problems connected with this sort of weed control differ from the general work on agricultural weeds. In most cases fishlife, and often wildlife generally, have to be conserved and a selective poison harmless to other species has to be used. In coastal waters and tidal estuaries there is the problem of dilution and tidal periods. In America, in particular, considerable research has been made into this subject in recent years, and for the first time some reasonably safe herbicides of a systemic nature have met the joint needs of river boards and fishery interests.

In the case of the Kariba weeds, the matter is more of a temporary growth than the choking of the sweetwater sections of the Suez Canal, the overgrowth of *Spartina* in Poole Harbour and the Cheshire Dee, and the seasonal growths of algae and diatoms familiar to most waterworks engineers.

Some 10% of the water surface of Lake Kariba is covered with *Salvinia* and *Pistia*, as well as sedges and aquatic grasses, and 2,000 sq miles are expected to be covered before the rising level of the lake makes their growth less likely. They have thrived in the shallow hot water, and were fertilised or fed by the minerals washed in from the newly flooded land.

To some degree aquatic vegetation can be controlled by varying water-levels, or even by dragging and raking surplus weed out of the water, but in large areas of dense growth, chemical control becomes the only effective method. This sort of treatment is best made with the young growth in late spring or early summer before the full growth is attained, otherwise a secondary problem may arise from the mass of dead vegetation left to foul the water and affect fishlife either as a result of decay or by the side effects resulting from the larger amount of chemical than necessary. Methods of treatment depend upon which of the botanical zones of growth are to be dealt with; these can be shallow marginal growth (often subaquatics, like rushes, with a large amount of aerial growth), floating growth, which generally has broad surface foliage, or submerged growth, which is often in deep water, but usually has a seasonal aerial growth at flowering time. Furthermore, another zone of bank growth, even including trees like willow, sallow, alder and others, may become undesirable if they abstract too much water from small industrial reservoirs.

In recent years common water-milfoil has become established in several states in the USA, and is flourishing in such dense beds that boating, fishing and wildfowl facilities are seriously affected, for it tolerates brackish as well as freshwater, and unless preventive measures are taken, it seems to conquer far more situations than in Britain where it is in competition with other plants. This plant has been found commonly in water tanks in Syria, but not to such excess.

In the control of certain aquatic weeds in Missouri, C. R. Walker was able to control effectively many submerged weeds by using special floating distributors with the water-soluble fertiliser 16-20-0 (the figures represent the relative percentages of nitrogen, phosphorus and potash). Other NPK mixes were inferior to this, but in all cases distribution from a floating platform was more effective than broadcasting it in the water. In some of his experiments, small waters were divided into two, or into several sections, by vinyl plastic sheets supported by floats like certain fishing nets, in order to see the effect of various fertilisers and herbicides. It was also found, as has been shown elsewhere, that the use of herbicides in the form of pellets lasted longer and was more effective than liquid applications.

Here, as elsewhere, pellets of Dalapon-2, 4-D mixture and of Simazin were found to be harmless to fish or fish-food, Simazin controlling most of the submerged species. In America, the chief herbicides used to control aquatic weeds are Benocolor, 2, 4-D, solvent naphtha, CMU and sodium arsenite. In tidal areas, quick destruction or quick absorption is necessary before tidal dilution and, where sea-fisheries exist, some chemicals in the latter list would be too toxic. Dalapon and Amitrol were shown by Levi in Australia to be satisfactory in controlling the growth of *Typha* (reed-mace, cat-tail, etc.), also rushes, and sedges in freshwater channels with fluctuating water-levels. Amitrol gave complete control for at least 15 months, and the ethyl ester of 2, 4-D applied at the rate of 16 lb/acre in oil emulsion gave good control of narrow-leaf cat-tail, especially when used on the five-leaf to seven-leaf stage of growth, and when water levels could be maintained at a depth of 3 ft after treatment. Care must be taken to avoid outfalls contaminating lower water, or farmstock from drinking treated water.

Dalapon, which is also the active ingredient in a newer American herbicide being used in this country, called Dowpon, is chemically 2·2 dichloropropionic acid. It was used successfully in the Poole Harbour experiments to control the excessive growth of *Spartina townsendii*, or rice cord-grass, a vigorously-growing perennial with creeping rootstock, which causes considerable silting trouble in many tidal waters, as it can withstand many hours of submergence. The use of Dalapon at the rate of 50 lb/acre by Ranwell

and Downing produced a 100% kill of all *Spartina* growth one year after its application, in July, by spraying. Recolonisation by seedlings, probably arriving from outside the sprayed area, necessitated repeat applications. The use of Fenuron at 40 lb/acre gave a 99% kill when applied in April, and a year and a half after spraying with it there was still no significant regrowth. A pellet combining Fenuron, 2, 4-D and sodium borate injected into the mud or sprinkled on the surface at 15 lb/acre killed 60% of the *Spartina* in the tidal area.

Dalapon, of course, acts through the roots or leaves to penetrate the whole plant tissue as a systemic chemical, without necessarily contaminating the surrounding water. Freshwater fish placed in cages in channels so treated in Kent and Lincolnshire were found to be unaffected, though by October the dead plants remained to decay in the water. These, if dry, could be burnt of course. Its use compares favourably with the high cost of labour to cut reeds and reed-mace. One man with a knapsack sprayer covered 42 chains of ditches in two days on widely separate sites on Romney marsh, at a cost of £36 10s./mile, of which £8 4s. was the cost of labour. Cutting the same area of reeds by hand cost £40–£80/mile, and had to be repeated annually by cutting or using a dragline.

Provided that they are not standing in water deeper than 12 in, reeds, reed-maces and rushes can be controlled in this way, with only minor sproutings and occasional regrowth in the following year. A second treatment will of course eliminate all regrowth except that originating from any seeds in the soil or mud. In low volume spraying an additional non-ionic wetting agent like sodium dialkyl sulphosuccinate has been used. An application of 25 gal/acre was made in a 250-gal mixture, using an orchard spray gun for a solution of 10 lb dissolved in 100 gal. For a 20-lb application mixed in 7 gal, application was either by mist spray or from an aeroplane. A solution of 3,000 p.p.m. of Dowpon caused no harm to freshwater fish in American experiments, but 5,000 p.p.m. would kill them. A wetting agent makes it unsuitable to use more than 300 p.p.m., a concentration unattainable by spraying. At 200 p.p.m. it will not kill arthropods (crayfish and other crustaceans, and insects) or other fish food.

This systemic herbicide kills the water plants slowly, hence it is claimed that there is smaller decay. It is best applied in early summer when the reeds are small. Against reed-mace and reeds, a strength of 20 lb in at least 100 gal of water was applied with a spray boom from an orchard spray gun over the reeds. Tough reed-mace required 10 lb in 100 gal and 200 gal or more of this may be required to wet all the foliage thoroughly.

The further addition of 8 oz/100 gal of a wetting agent such as Teepol is recommended. After regrowth, the reeds are sprayed with 15-20 lb/acre, or spot-sprayed at the rate of 10 lb in 80 gal. In swampy areas, spraying by aircraft using 20 lb in 7 gal of water was found effective. The addition of 2, 4-D or 2, 4, 5-T esters to Dowpon is better for the control of more broad-leaved weeds or woody plants. Woody plants can often be flooded out.

Much of the application strength and the cost depend, of course, upon the width of the ditches, streams or lakes. A 6-yard wide ditch requires 0·55 lb/chain. Dowpon when imported is supplied in 50-lb drums at 12s. 6d. in the United Kingdom. At 20 lb/acre, a chain costs 6s. 10d. to treat. Retreatment the following year at 15 lb/acre or 0·41 lb/chain costs 5s. 2d. a chain. No health hazard is known to its users except an irritation to the eyes and possibly to the skin, but the chemical can be washed off by immediate treatment.

*Fig. 1. Water-Hawthorn or Cape Pondweed (*Aponogeton distachyum*)—a pest in Australia and South Africa*

In field tests in Massachusetts, Boschetti has shown that Kuron is effective against most aquatic weeds at a contact concentration of 2 p.p.m., with the exception of *Potamogeton* (especially in deep water) and *Sparganium* (bur-reed). The *Potamogetons* are amongst the commonest groups of submerged and floating pondweeds. Kuron also has some residual effect, for cleared areas remained free for more than a season. Its effect on the aquatic fauna is chiefly a temporary change in plankton. Eipper, of Cornell University, has tested the effect of five particular herbicides on water weeds, by 70 applications to 30 ponds, according to their physical conditions. When applied as surface sprays to produce 0·5 p.p.m. by weight of active ingredient, copper sulphate, Delrad and Fermate were equally efficient in controlling unbranched flamentous algae, blanket-weed or green slime, the copper sulphate being the cheapest and least harmful to fish such as minnows. In the case of Phygon, a solution of 0·25 p.p.m. was harmless to fish—and also harmless to the plants. On the other hand, although sodium arsenite did not prove harmful to fish at 4 p.p.m., strength-resistant algae like *Hydrodictyon* and *Cladophora*, etc., as well as rooted plants, were controlled.

In these types of tests numerous controls are needed, as well as replicates and careful measurements of results. A number of variables may confuse

the issue, and different concentrations react differently. Greeley and Steenis showed that in pellets of vermiculite and attaclay, a complete kill of American water-chestnut without regrowth was achieved only by 2, 4-D, especially when in a soluble form (amine salt). Where surface sprays were employed, a change in specific gravity was necessary to provide a slow sinking herbicide, e.g., the addition of tri-ethanolamine. Aerial application needs care to avoid drift on to nearby crops.

Scheider found that Simazine, when used as high as 10 lb active per acre, was still harmless to fish and fish food, in areas where little or no run-off enabled the entire area to be treated at one time. Purple loosestrife defied several herbicides, but where it was too numerous for hand-pulling of its stems, ammate provided a satisfactory kill in both wet and dry positions. In many parts of America this colourful marginal semi-aquatic plant increases to pest effect where drawdown of water supplies encourages its rapid increase. Surber showed that 1 to 2 p.p.m. sodium arsenite in water killed *Elodea* (Canadian water weed in Britain), hornwort and many *Potamogetons*. *Elodea* is most resistant, and *Chara* (stonewort) almost totally so.

Steenis, Everett and Beck have shown that a mixture of Dalapon and Amitrol is superior to other herbicides in the control of common *Phragmites* reed, an almost universal shallow water or marginal semi-aquatic. On dry sites the most effective and least expensive control was a mixture of 10 lb of Dalapon and 2 lb of Amitrol/acre. On wet sites a mixture of 25-30 lb of Dalapon and 4-5 lb of Amitrol/acre was applied during flowering and early fruiting stages with equal effect. Smaller amounts may be effective where the plant is less vigorous than on the Delaware marshes, where the trials were conducted. The cost of aerial applications is of course reduced if they can be accomplished in a single flight.

In eastern Texas, Goodrum and Gray gained a 95-99% control of giant cutgrass (*Zizaniopsis*) in water up to 3 ft deep, using Dalapon in late spring with the water-level lowered as far as possible. The latter gave maximum contact with plant foliage with the least chemical—75-125 gal/acre, at the rate of 20 lb/acre. Water was used as both solvent and carrier, with 30 oz of a detergent in 100 gal of the solution. A regrowth of 1% occurred when the water level was lowered sufficiently to expose the plant crowns.

Spray with 2, 4-D was found to be not sufficiently effective in the control of American water-chestnut, unless carefully timed. It was more effective in pellets of vermiculite, which take the herbicide direct to the bottom where the roots imbibe it. Clay pellets released the chemical too slowly. Aerial applications and sprays of Dalapon were found to be almost as effective on *Panicum* species and cat-tail with 10 lb/acre as with 20 lb/acre, with water-depths between 2 and 2½ ft. This was ineffective against *Zizaniopsis*, however, and following treatment, dense stands of other aquatic plants promptly invaded the gaps, e.g., *Echinocloa, Setaria, Panicum, Scirpus* and *Eleocharis*.

About 90% control of American cat-tail was obtained by aerial spraying with 10 lb/acre of Radapon (85% sodium salt of Dalapon) in less than 8 in of water. Again this was almost the same as when 20 lb/acre were used. It was applied in 4 gal of water, and the following year was free of trouble, but 35% regrowth occurred from a single application only. It left useful wildfowl food-plants unharmed. Late season applications of Dalapon and Amitrol were far less effective than early ones. Twenty lb/acre in split applications was more effective than 10 lb/acre in one application, and just as effective as 40 lb/acre. The addition of diesel oil as an emulsifier greatly increased the effectiveness of Dalapon on cat-tail, but not that of Amitrol.

One or more applications of sodium arsenite as an algicide at 4 p.p.m. gave fairly satisfactory control of *Pithophora* and *Hydrodictyon* when the algae were actively growing, but less when they were mature. The doses also destroyed fish food, resulting in poor growth of fish afterwards. Whereas copper sulphate and sodium arsenite are harmful to fishing interests in warm waters, Snow has shown that there is some advantage in the use of abietylamine acetate (Delrad) as an algicide.

Rushes, like many plants, vary in their reaction to chemicals according to the species. Three hundred and fifty species of rushes alone occur in the temperate and colder regions of the world. The common rush, *Juncus effusus*, is controlled by spraying 2 lb/acre MCPA or 2, 4-D amine, or 1 lb/acre, 2, 4-D ester, at the time of their early flowering. They are then cut. However, *J. inflexus, J. articulatus* and *J. squarrosus* are more resistant to these herbicides.

In the case of algae (blanket-weed or slime-plants) in water, the effect of chlorine and copper sulphate on different species varies greatly. The usual chlorine concentration of 1 p.p.m. is very near the toxic level for fish. In a fishery the dose is half this, but it does not kill all algae species.

Any excess of chlorine is more rapidly removed by the action of other compounds in the water than is an excess of copper sulphate. Sodium sulphite and thiosulphite may be used to destroy residual chlorine, but this itself is very toxic, even at 100 p.p.m.

The efficiency of water-weed chemicals may be affected by the composition of the water and the properties of the mud. The greater the quantity of dissolved salts, the less effective the chemical. Thus a greater dose is needed with consequently greater side effects. The rapid flow in streams makes contact poisons more difficult to apply. Until recently, sodium arsenite was the only effective treatment, which was also harmless to fish and their food if not in excess, for submerged water-weeds. Chlorine only checks their growth, and agroxone needs too great a quantity to destroy more than aerial growth. Sprays of 2½% of sodium chlorate are effective on reeds and marginal growth without harming fish, and in running water it may be used by injecting it into the roots or mud, or growth patches, with the aid of a pointed metal tube from the sprayer.

In addition to chemical methods there are of course biological methods of control, which would require separate discussion. Similarly, the general treatment of algae is rather different from water plants of the higher groups covered here.

Forward Twin-Bucket Weighbatcher. A new version of this weighbatcher has been produced by Thos. W. Ward Limited, Albion Works, Sheffield, England, and its main features are described in a pamphlet that we have received. The main modification introduced is in the frame, which is now constructed with rectangular steel tubing instead of angle sections.

The Dorfertal-Huben Project

A description is given of the first project, which is now under construction, of a proposed multi-stage development of the Isel valley in Eastern Tyrol. This high-head plant will have an installed capacity of 150 MW

By DR. ERWIN KÖNIGSHOFER

NORTHERN and Eastern Tyrol have a mountainous terrain and are rich in hydro-power resources, which are particularly favourable to the development of storage plants. Soon after the end of World War II the Austrian Government set up a study company, which was commissioned to investigate the hydro-power resources of Eastern Tyrol and to put forward proposals for their development. The Isel, a tributary of the Drau, flows through Eastern Tyrol, and is joined by many tributaries. The study company have proposed a five-stage project for the Isel valley, and urge the development of the stages on the basis of international co-operation by the "Interalpen" (Study Company for the Development of Alpine Water Power in Austria). Since the time is not yet ripe for initiating such international co-operation, it was decided to proceed with the development of one of the five stages, the Dorfertal-Huben storage scheme. The construction project was prepared for the study company of Eastern Tyrol by the Tauernkraftwerke AG, and site work has now commenced.

Fig. 1 shows the layout of the planned power development. In the Kalser, or Dorfer, valley a site has been found that appears to be particularly suitable for the establishment of a reservoir. The water is to be impounded to a maximum level of 1,730 m and a minimum level of 1,630 m. As the run-off from the relevant catchment area will be insufficient to fill the reservoir, the following tributaries of the Dorfer are to be diverted: the Teischnitz, Ködnitz, Berger, Peischlach, Vollpremoa, Lesach, Mittêrling, Strojes, Falschretz and the Gössnitz. These streams drain the relatively high run-off from the glacial Glockner massif in the upper part of the Dorfer valley.

The project comprises the following main works: a dam for creating the storage reservoir of 100 million m³ capacity; a low-pressure tunnel, 10 km in length, including a surge tunnel and a valve chamber;

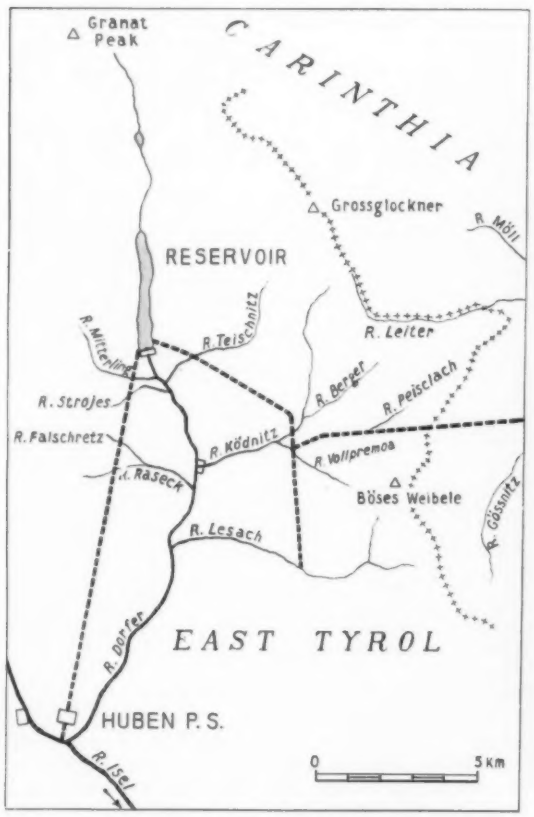


Fig. 1. Layout of proposed development

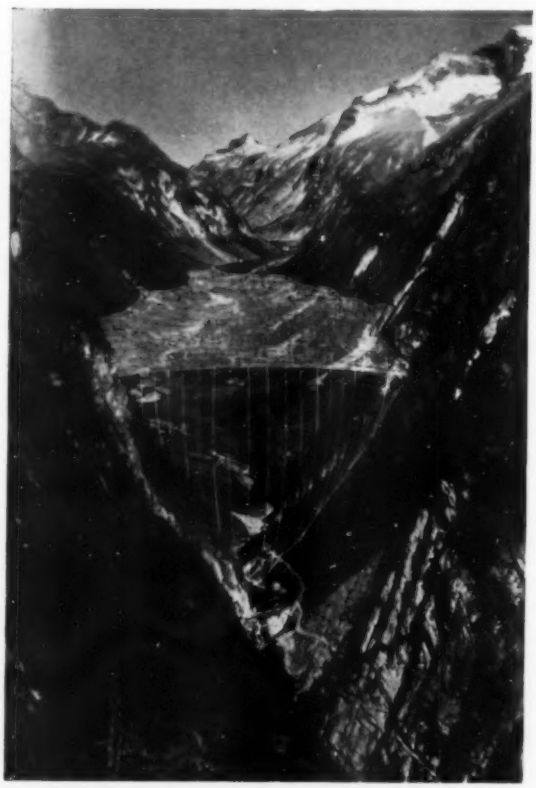


Fig. 2. The Dorfer valley site, with the proposed dam shown superimposed

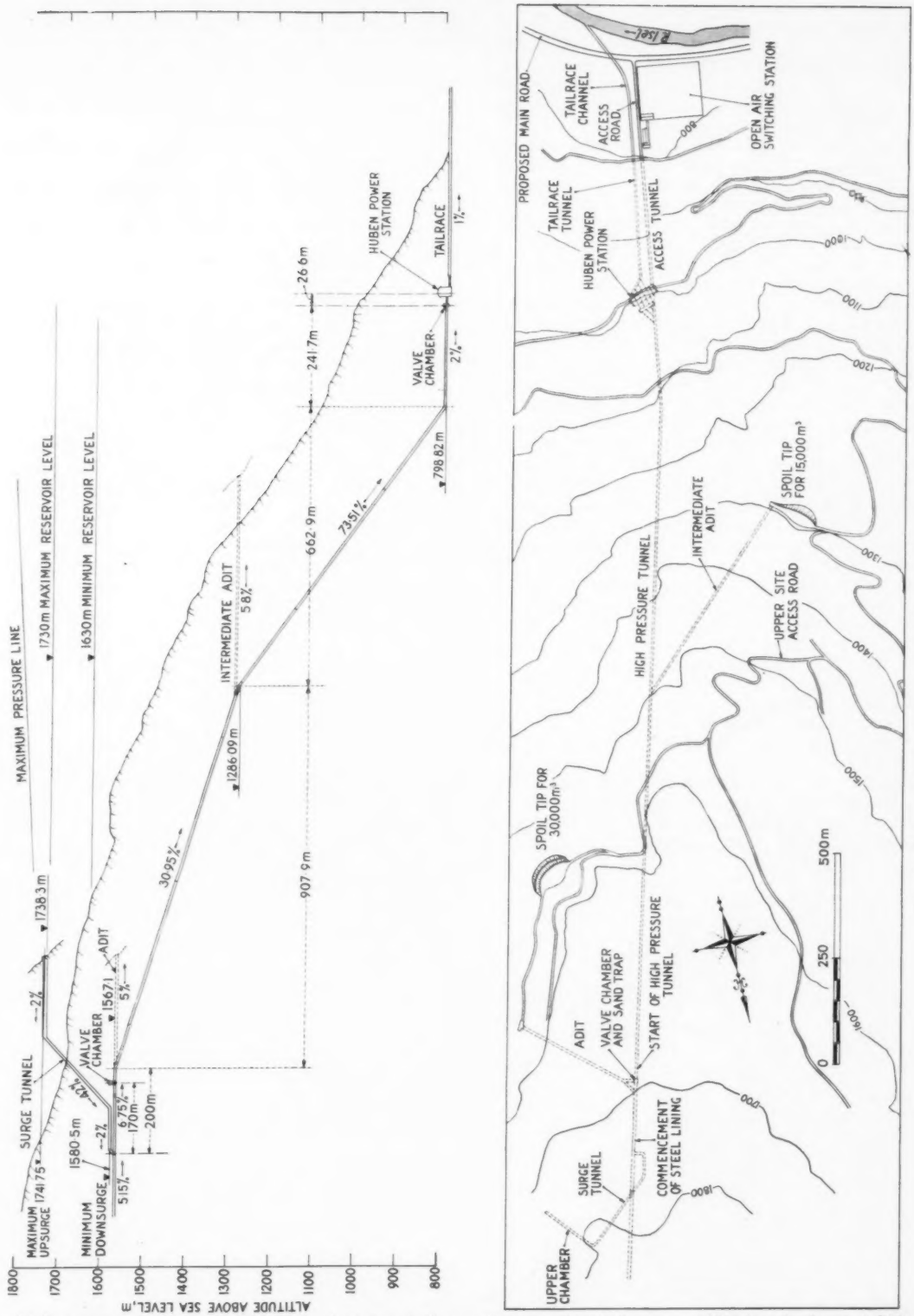


Fig. 3. Plan and longitudinal section of the tunnel system

a high-pressure tunnel; an underground power station with an outside control room, switching station and workshops; a tailrace tunnel and channel; and the stream intakes. In view of the fact that the building sites are located at an altitude of about 1,800 m above sea level, and that extensive excavation and concreting work will be required, much preparatory work is necessary.

Preliminary Works

Construction of the complete project will involve the transport of about 110,000 tons of cement, including 85,000 tons for the dam alone, and about 5,000 tons of pipes for the steel-lined section in the tunnel, as well as machinery and aggregates.

The 20-km road from the railway station at Lienz to the proposed Huben power station requires improvements so that heavier loads can be transported. Provision for adequate feeder track, loading points with cranes, and unloading points for the cement wagons has also to be made. The existing road from Huben to the dam site must be widened and strengthened over its whole length of 20 km, and be provided with passing places in order that it can be used by the 31-ton silo-cars, which carry 17-ton loads of cement. In particular, the last part of the road through the Daba ravine, where gradients up to 15·7% occur, will have to be widened in order to permit the transport of construction plant. Aggregate will probably be obtainable in the storage area, but new roads will be needed to convey it to the preparation and mixing plants. For the construction of the headwater conduit, cableways will be required in addition to access roads.

The excavation of the high-pressure tunnel will be assisted by the driving of an intermediate adit, to which a road will be made, and a cableway to the surge-tunnel site will also be necessary.

Access to the stream intakes will be by means of short roads, which will be constructed to the tunnel portals. The building sites are to be supplied through these tunnels as far as possible.

Features of the Dam

At the available head the storage volume of 100 million m³ represents a production capacity of 194 million kWh.

The dam will be constructed as a thin-arch structure in cupola form, the maximum height of which will be 164 m. Other leading dimensions will be as follows: crest width 3 m; thickness at abutments 30 m; crest length about 250 m; crest radius 160 m. Some 323,000 m³ of concrete will be needed for the structure, and the foundations will require the excavation of 127,000 m³ of rock and 186,000 m³ of soft material. Fig. 2 is a photograph of the site with the proposed dam superimposed.

The intake conduit, which will be located at a height of 1,624·5 m, will cross the dam on the downstream side to the right bank, where, after a distance of 100 m, it will join the low-pressure tunnel. The piping will be roofed over with a reinforced-concrete construction, and covered by earth. The valve chamber containing the main butterfly valves, 2·2 m in diameter, will be on the downstream side of the dam.

The sluice-valve intakes will consist of two conduits, one of which will be 360 m long and have a diameter of 2·8 m, and the other will be 260 m long and have a diameter of 1·6 m. The valve chamber, containing double-jet butterfly valves, will be at the end of the tunnels, and will be accessible from the road. The spillway is to be on the right bank, 20 m from the dam abutment, and will consist of a syphon weir designed for a flow of 80 m³/sec, and a discharge tunnel 2 m square and 180 m long.

The Tunnel System

The low-pressure tunnel will have a total length of 10 km, and will be concrete lined. In places, depending on the nature of the rock, it will also be lined with gunite, which will be 5 to 10 cm in thickness. It will have an inside diameter of 2·6 to 2·7 m and is designed for a maximum flow of 23 m³/sec. The maximum velocity of the water will be 4·33 m³/sec, and the maximum gradient is to be 5·83%.

The low-pressure tunnel will be advanced from three openings. Raseck adit will be 142 m long and have a profile of 2 m by 2·2 m. From this adit the tunnel will be advanced over 3,391 m towards the intake, and 1,273 m downstream. The section beneath the Raseck stream, which will have an inside diameter of 2·6 m, will be steel lined over a length of 623 m. The working shaft for the lining will be

TABLE I.—HYDROLOGICAL DATA FOR AN AVERAGE YEAR

Stream	Catchment area		Utilisable flow					
			Winter		Summer		Year	
Dorfer	km²	42·1	m³ × 10⁶	8·4	m³ × 10⁶	54·7	m³ × 10⁶	63·1
Teischnitz ...	11·5		2·1		12·4		14·5	
Ködnitz	9·3		1·7		10·0		11·7	
Berger	2·4	31·5	0·4	5·7	2·6	34·0	3·0	39·7
Peischlach ...	4·3		0·8		4·7		5·5	
Folpremoa ...	4·0		0·7		4·3		5·0	
Lesach	16		2·9		17·3			
Mitterling	2·9	20·0	0·3	3·2	1·7	19·8		23·0
Strojes	0·7		—		0·5			
Falschretz ...	0·4		—		0·3			
Gössnitz		27·2		4·9		29·4		34·3
Total		120·8		22·2		137·9		160·1

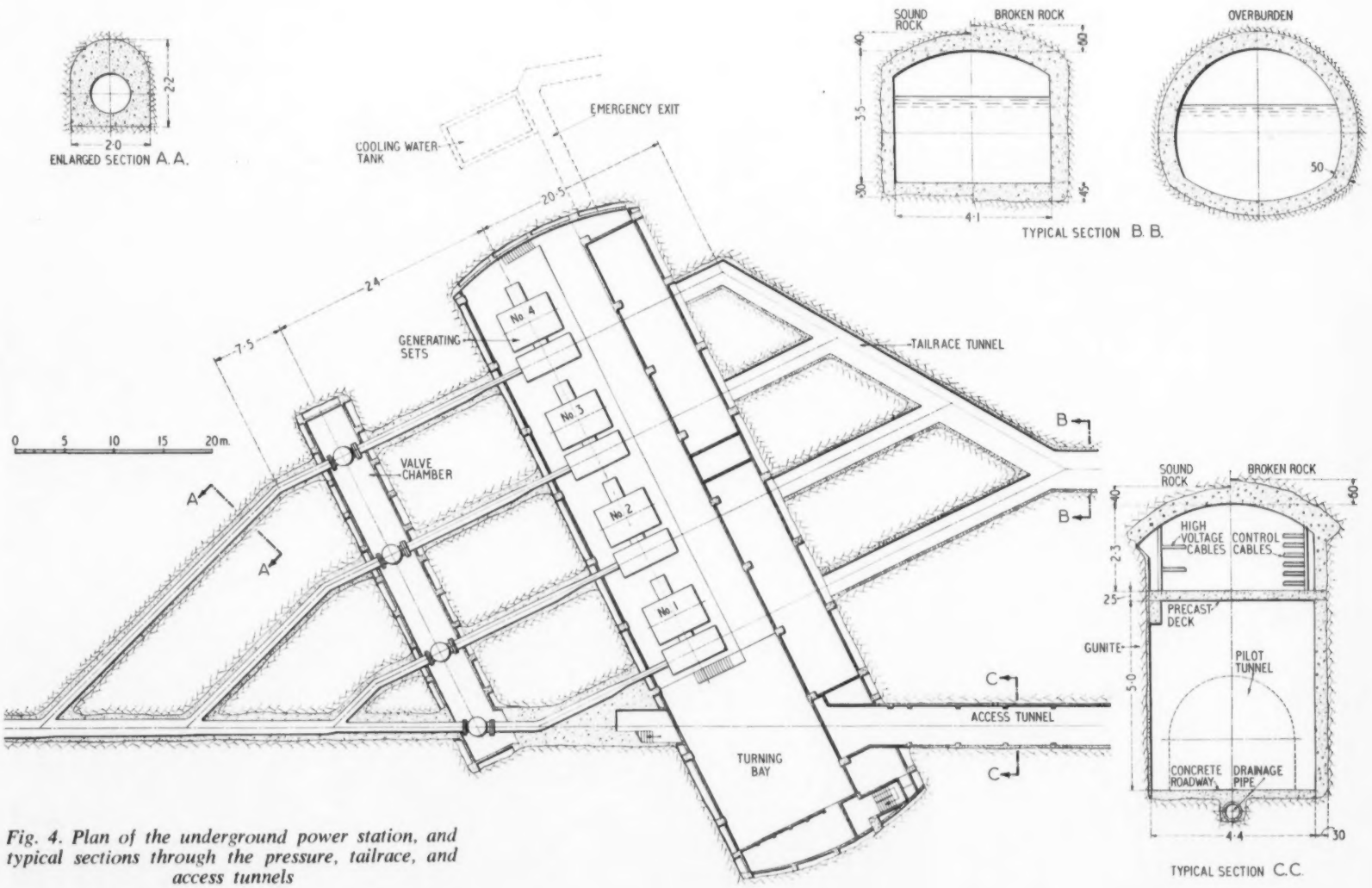


Fig. 4. Plan of the underground power station, and typical sections through the pressure, tailrace, and access tunnels

TABLE II.—ESTIMATED SUPPLY AND OUTPUT DATA FOR AN AVERAGE YEAR

	Winter	Summer	Year
Available water supply	22·2 $m^3 \times 10^6$	137·9 $m^3 \times 10^6$	160·1 $m^3 \times 10^6$
Storage	+100 $m^3 \times 10^6$	−100 $m^3 \times 10^6$	0
Utilisable water supply	122·2 $m^3 \times 10^6$	37·9 $m^3 \times 10^6$	160·1 $m^3 \times 10^6$
Mean annual utilisable flow	21·5 m^3/sec		
Maximum gross head	934 m		
Mean gross head	900 m		
Minimum gross head	834 m		
Mean net head	837 m		
Energy equivalent of storage	194 million kWh		
Installed capacity	150 MW		
	Winter	**Summer**	**Year**
Duration of full-load operation	1,580 h	495 h	2,075 h
Output	237 kWh × 10^6	74 kWh × 10^6	311 kWh × 10^6

accessible from the road.

The Arnig adit will be 780 m long and have a cross section of 2 m square, and access will be by means of one of the cableways. From this adit the tunnel will be advanced some 1,808 m upstream and 2,092 m downstream.

The adit at the surge-tunnel site will be 300 m long. Thence the tunnel will be advanced over 1,324 m upstream and 60 m downstream. The steel-lined section will be 190 m long and will have an inside diameter of 2·6 m. The surge tunnel will comprise two chambers connected by an inclined shaft, and will have a concrete lining 20 to 45 cm thick. The upper chamber will have a volume of 1,800 m^3, and the lower chamber a volume of 530 m^3. The connecting shaft will be 237 m long and will have an inside diameter of 2·5 m.

The valve chamber will be accessible by means of one of the cableways. A vertical-lift gate, 2·25 m by 2·25 m, will be installed in the chamber, and will be employed as a safety device against pipe fracture.

The inclined high-pressure tunnel will be steel lined, and will have a length of 1,750 m and an inside diameter of 2·1 to 2·6 m. It will be driven from an intermediate adit, the portal of which will be accessible from a new road, 1.3 km long. The high-pressure tunnel will be terminated in a horizontal section, the total length of which will be 587·5 m, including a 324-m extension to form an access tunnel (see Fig. 3). The gradient of the horizontal high-pressure tunnel will be 2%, and its inside diameter 2·0–2·1 m.

The Underground Power Station

Fig. 4 shows the underground power station with the four generating units that are to be installed. Four steel penstocks, each with an internal diameter of 1 m, will branch off from the high-pressure tunnel to a valve chamber, where four spherical valves, 0·9 m in diameter, are to be installed. Connecting pipes lead from the valves to the four generating units in the machine hall. Each of the four units, which have a total capacity of 150 MW, consists of a 63,000-h.p. double-nozzle Pelton wheel utilising 5·35 m^3/sec, and a three-phase synchronous generator rated at 42 MVA, 10 kV, at a speed of 500 r.p.m.

Two transformer banks, each consisting of three single-phase transformers rated at 28 MVA, and stepping up to 220 kV, will be situated in the machine hall, and the control room and workshops will be erected outside. The open-air switchyard will be connected to the 220-kV transmission line that runs between Lienz and Kaprun.

The tailrace is to be partly in tunnel, having a cross-sectional area of approximately 13·5 m^2 and a length of some 291 m, and partly in open channel, which will have a length of about 200 m to the point where it joins the Isel. Its gradient will be 1%, and the embankment slope 2 : 3.

Hydrological and Output Data

The relevant hydrological and output data for an average year are contained in Tables I and II respectively. It will be seen from these that an annual production of 311 million kWh is anticipated. Of this total some 76% will be produced during the winter months, and this factor emphasises the value to Eastern Tyrol of this particular development.

Correspondence

High Earthfill Dams

To the Editor, WATER POWER

With reference to your editorial of July last, the claim of Mangla dam to be the highest earthfill dam is refuted by the now completed Trinity dam on the Trinity River in Northern California, the height of which is 537 ft above the lowest point of the foundations; the dam is a simple earthfill with a central impervious core. However, Oroville dam, the main unit of the Feather River project (WATER POWER, February 1959), which is now scheduled to be an earthfill, will be 730 ft high; construction is due to start in the fall of 1962. Even this height pales beside that of the Nourek dam on the Vakhsh River, south east of the Caspian Sea, which is under construction and will top out at 990 ft.

J. FETTES

Lewiston, California.

Seventh Congress on Large Dams

We publish a commentary on the proceedings of the Seventh Congress on Large Dams held in Rome from June 26 to July 1, 1961

PART TWO

Question No. 26: Modern Techniques for Concrete Dams for Wide Valleys, and Ancillary Works

THE wording of this question is such that it includes theoretical research work, for example Report R.59 by Zienkiewicz and others, testing large dams by models (Report R.23 by Rydzewski), methods of construction (Report R.7), test results, etc. A high proportion of the reports is concentrated on the description of modern dams, and deals with special problems.

Tests on shear strength between rock and concrete were carried out by the Working Group of the French National Committee (Groupe de travail constitué sur l'invitation du Comité National Français des Grands Barrages), which reports in Paper R.43. They summarise their tests by publishing an equation of the Coulomb type: $T = 30 + 1{\cdot}3\ N$ (kg/cm^2) where the shear stress T depends linearly on the stress N, perpendicular to T.

Investigating the lateral stability of buttresses in buttress dams (R.23), Rydzewski (Southampton University) tested some models under hydrostatic loading. The results indicate that lateral instability may not be as important a factor in the design of buttresses as has hitherto been thought.

Fundamental research on buttress and on multiple-arch dams is the subject of Report R.95 by Rocha, Serafim, Fernandes, and da Costa (Portugal). This team of well-known Portuguese experts gives most interesting test results of stresses in buttresses for different ratios E_c/E_f of the moduli of the concrete (E_c) and foundations (E_f). A study of multiple-arch dams with wide spans (arch span about twice the dam height) is mainly based on the new method of elastic membranes. A bibliography of some of the previous work of the Lisbon Research Stations is most useful.

L. Guitart (Spain), in Report R.122, discusses results obtained by measuring stresses in a buttress dam. He concludes that in buttress dams the influence of the foundation is more important than in gravity dams. The modulus of elasticity of the rock must be measured to be included in the analysis of stress. Stresses in buttresses of different height must be ascertained, as the most dangerous condition may occur in buttresses smaller than the highest. Load transmissions between contiguous buttresses must be studied on a model.

Zienkiewicz, Veltrop, and Shieh study the "Stresses at the Base of Long Spillways and Other Cantilever Walls" (Report R.59). This is a mathematical study leading to Airy stress functions and to an equation of the Laplace type, solved on a digital computer. The authors publish diagrams, tables and curves which will be of great interest to the specialised designer.

Veltrop has submitted a second paper (R.113), in which he examines the effect of hinges on stresses in dams, mainly in the case of curved dams in wide valleys (ratio of crest length to dam height equal to, or higher than, 10 : 1). Correct location for hinges and practical design suggestions are submitted. (A similar solution is described in Paper R.10 by Bellin and Laroche from France.)

Uplift problems under dams are discussed by Micucki (Poland) in Report R.107.

A description of the Grandval dam is published by Terrassa and Gautier (R.3). The dam height is 88 m, including 10–12 m of excavation, crest length 330 m, and the length at base 70 m. The dam has six sloping arches and seven buttresses, 5·50 m thick, with their axes 50 m apart. The wide spacing of the buttresses provides room for the power station. This dam was built by Electricité de France, and is a Coyne-Bellier design. Other French dams designed by A. Coyne and J. Bellier are described in Paper R.10.

Russian experience is described by Rousseaux and Likhachev in Paper R.111 on "Experience of Designing and Construction of Large Dams on Rivers of the Plains in the USSR." Thirteen different dams are described and discussed (see Tables 1 and 2 of the paper). The authors describe three different types of dams, depending on the position of the spillways and gates. Unit discharge of water released over a dam per linear-meter width of the downstream apron is up to 55 m^3/sec for clays and up to 45 m^3/sec for sands. For new dams now being studied, it is considered possible to step up the unit discharge to 60–70 m^3/sec in some cases. Recent Russian experience has been in favour of less massive designs, conveniently reinforced, and with hollow members. Earth dams have been built in the USSR of hydraulic sandfill. Their maximum height reaches 80 m.

An Australian design of a prestressed dam (Catagunya dam) is described in Paper R.17 by Colebatch and Wilkins. The dam is 46 m high and is part of a 48-MW power development. Details are given of model tests, the testing of anchorages on models, the cables, the prestressing operations, and the design of a rather bold spillway. The estimated saving at Catagunya is of the order of 20% of the cost of a gravity dam. (It is suggested that the results of the anchorage tests by models described in this paper should be compared with an analysis of the tests made in situ at Allt-na-Lairige dam, reported in Report R.6 by Jaeger, and with a recent paper submitted by Zienkiewicz and Gerstner to the American Society of Civil Engineers (Paper 2714, Power Division, January 1961), dealing with the stress analysis of prestressed dams.)

Schulz, Scrivner, and Copen from the USA presented a Paper (R.62) on "The Study of a Curved

Dam in a Wide Valley." The dam is a concrete gravity structure 94·49 m high, 1,063·1 m long at the crest, 6·1 m thick at the top, and 81·38 m at the base. (Volume = 1,552,900 m^3 of concrete.) The analysis is by the trial-load method.

Report R.75 by Buchmann and Hautum on the Teisnach dam (height-to-length ratio 1 : 6·5) is extremely valuable. It compares calculations on the dam foundation settlement with measurements in a nearby tunnel, and discusses safety factor on the basis of calculated tensile stresses and measured strain.

Another paper from the USA by Fairbanks and Sutherland (Report R.61) deals with "Design Features for Safety and Economy in Dams for Wide Valleys."

Examples of massive gravity dams and rockfill dams are given in the paper. Foundation preparation and seepage prevention are examined in chapter 3; chapter 4 contains useful rules for the junction of earth wings to concrete dams.

Goodhue reports on the "Corps of Engineers Planning and Overall Design of Concrete Dams in Wide Valleys" (R.60). This paper contains very valuable information on foundation problems (chapter 3), including in-situ field shear tests, grouting and drainage. Figures concerning shear safety factors are also published in chapter 4 on "Stability."

The construction of Long Sault dam on the St. Lawrence is described by S. N. Smith (R.53).

Mura, Tankada, and Tomidokoro (Japan) describe a "Twin Arch Dam Constructed Across a Wide Valley" (R.31). Structural model tests were done with the stress-freezing process. Full details are given of the loading apparatus used to apply centrifugal forces during the photo-elastic experiment and on the physical characteristics of the photoelastic material (Araldite B-type). Hydrostatic loads were simulated with either microwax or asphalt, either of which was heated during the tests.

The second part of the paper deals with the correct hydraulic shape of the spillway on top of the left arch. Table I compares volumes of excavation and of concrete, maximum stresses, type of spillways and gates, and total costs for different design alternatives.

Twenty-five large Scottish dams are described in detail by L. H. Dickerson and R. R. Morton in Paper R.25, "Review of Some Recent Dams Built for Scottish Conditions." Tables give details on the dam type, height, total length and volume. For three buttress dams the maximum stresses in the buttresses are given; figures and diagrams show details of a fishlock (Orrin dam), of facing blocks (Cluanie and Moyne dams) and of a dam abutment (Meig dam). The paper gives detailed information on designs, flood-discharge provisions, concrete, grouting, water seals, etc.

Semenza, the Italian expert, Manager of SADE, describes the Gusana dam, an asymmetrical arch dam in a wide valley (Paper R.115) and the Pieve di Cadore and Fedaia dams (R.117). In this last Report, details are given of several alternatives studied for Pieve di Cadore before the final design was adopted. Deflections of the dam crest versus temperature-variation curves are shown on Fig. 8 of the same Report.

Lotti (Italy) describes the Tarsia dam (Paper R.116).

Papers were also sent from Norway (Gröner), Finland (Korvenkontio), and Czechoslovakia (Kraus and Jirsak). R. Prisu from Roumania compares different dam types for economy in concrete. He investigates the influence of an inclined upstream face and concludes that " . . . The theoretical concrete saving also increases according to the hollowing coefficient and is of the order of 10–15% in the case of enlarged-joint dams and of 25–40% in the case of hollow gravity dams and of round-head buttress dams."

The Erraguène dam is described by M. Durand in Report R.83. It is an 86-m high multiple-arch dam with 3-m thick buttresses, and 35-m buttress spacing. The buttresses are prestressed with Freyssinet jacks. The arches are not cylindrical but have double curvature, which stiffens the buttresses laterally. Stress distribution has been studied both theoretically and by model tests. The Freyssinet jacks have allowed for a substantial reduction in concrete.

Dr. K. L. Rao (India) gives a detailed account of "Modern Trends in Design and Construction of Dams in India."

The General Report on Question 26 is by M. Rocha and J. Laginha Serafim, from Portugal.

The discussion on Question 26 was extremely well attended. Several speakers simply emphasised the gist of their reports. There was a vivid discussion between Prof. Zienkiewicz (USA) and Trollope (Australia), who obviously do not see the problem of dam foundation from the same point of view. Trollope emphasised the importance of the lack of homogeneity of rock used for foundations, whereas Prof. Zienkiewicz thinks a mathematical analysis of stress distribution in foundations is the first useful step to be considered. Among the prominent speakers were Xeres and Serafim (Portugal), Puls (USA), Prof. Oberti (Italy) and many other well-known specialists. At the close of the discussion, C. Marcello (who two days later was elected the new Chairman of the International Commission on Large Dams) gave a most interesting demonstration of the different types of dams he has designed during his long career as Chief Consultant to the Edison group, Milan.

Question 27: Sealing of Earth and Rockfill Dams with Bitumen and Other Materials

In the introduction to the General Report on Question 27, G. E. Bertram (Chief of Soils Branch, Department of the Army, USA) remarks that about one-half of the reports deal with bituminous concrete for waterproof facings or impervious diaphragms for earth and rockfill dams. The other reports examine the following aspects of the question: Foundation treatment by grouting; seepage control by means of upstream blankets, sheet-pile cut-offs and downstream drains; impervious linings for high-level pumped-storage reservoirs; waterproofing of embankments by means of steel facings, reinforced-concrete facings or precast-concrete facings with plastic film liners; and sealing of embankments by means of centrally located earth cores.

The subject of foundation treatment under embankments was given very complete coverage under Question 16 of the Fifth Congress (Paris, 1955). Additional information is contained in some of the reports submitted under Question 27. Czyzewski and others from Poland (R.106) report on the successful cement grouting of steeply dipping beds of alternate sandstone and shales. Bituminous grouting was used in USSR in interbedded clay and sandstone (Nitchiporovitch and Sidorov, R.123). Dixon and Perrott (Great Britain, R.6) report in detail on the foundation treatment at

the site of the proposed Guma dam, Sierra Leone and the sealing of fully lateritised rock by means of clay-cement grout. Brown (R.67, USA) brings most interesting information on the effectiveness or otherwise of the treatment of the foundation of Chief Joseph dam, McNary dam, Dalles Closure dam, and Hills Creek dam. Success at McNary dam is compared with difficulties encountered at Chief Joseph dam. On each project, the decrease in seepage quantity during the period of operation has been attributed to natural or artificial siltation in the immediate area of the dam. Dams built in the USA by the Army Corps of Engineers are discussed by Lane and Wohlt (R.65). Twenty years of observations show that upstream blankets have increased in effectiveness, which is attributed to the formation of silt layers. The effectiveness of steel-sheetpile curtains has been shown to be small, at least in the early years of reservoir operation. These practical results should be compared with a most interesting theoretical research by Kratochvil and Halek (Czechoslovakia, R.108) on the relative efficiency of different types of vertical cut-off walls and horizontal blankets. The main variables considered by these two authors are the relative thickness of the pervious foundation (dam height is taken as $H=1$) and the relative perviousness of foundation material and cut-off wall or blanket.

Methods for sealing earth and rockfill dams can use either steel, concrete, plastics or bitumen.

One French dam (R.19, by Destenay and Lemay) has been successfully sealed by an elastic steel facing on the upstream dam slope. Steel facing has also been used for a new type of concrete-block dam introduced by the Edison Company, Milan (Contessini, R.119).

Concrete facings have been used with limited success (R.19 and R.103).

On the experimental dam of Dobsina, Czechoslovakia (Hobst, R.97), a plastic film forms a continuous waterproofing membrane between two layers of corrugated precast concrete slabs. The operational experience is too short to permit conclusions.

Bitumen has been used widely. Van Asbeck (Great Britain, R.5) gives a general discussion on the use of bitumen. His report contains a valuable bibliography on the subject. A detailed comparative study, based on laboratory research on comparative advantages of the use of bitumen or sandy gravel for a 150-m high dam is contained in Report R.38 by Schnitter and Zeller (Switzerland). Important information is also contained in reports by Löhr (R.77, Germany), Walker and Ellsperman (USA, R.66), and in Portuguese, Russian, and other reports.

Report R.103 by the Working Group of the French National Committee on Large Dams summarises French experience, which can be compared with the General Reporter's own conclusions, which are worded as follows:

"With regard to embankment design, certain general conclusions can be formulated for embankments in three categories of height:

"*Under 50 m.* Settlement and deformation under water load are moderate, with the possible exception of dumped and sluiced rockfills. Therefore, steel, bituminous concrete, Portland-cement concrete, and earth are all adapted to use as a sealing material.

"*50 to 100 m.* Settlement and deformation are of significance and shearing stresses in the plane of impervious surface seals are important. Differential settlement assumes major significance for earth cores. Upstream surface facings of all types, as well as earth cores, have been used. However, the problems introduced by gravity forces, water loads, and shear stresses present major problems for the designer.

"*Over 100 m.* Dams in this range of height are either earth and rockfills with compacted cores, or dumped and sluiced rockfills with articulated concrete facings. Earth cores have been the most widely used and present many advantages. Considerable latitude can be exercised in the treament of the foundation under an earth core. Provision for reservoir drawdown for repair of a facing need not be contemplated. Requirements for erosion protection and wave action are amply met by the outer zone of the upstream shell."

Communications

Several of the papers submitted to the Congress as Communications have already been mentioned in connection with Reports.

Paper C.13 by Janod (France) on the behaviour of steel-lined shafts (tests in the Roselend shaft) and Paper C.8 on sliding-friction tests on sedimentary-rock specimens could have been dealt with under Question 25. Paper C.13 is an important study on strains and stresses in steel-lined tunnels. Paper C.23 on the large Inga dam project in the Congo (by Pahud and Afschrift) and Paper C.2 by Japanese authors on "Designs of Arch Dams in the Multipurpose Projects of Japan" could have been submitted under Question 26 or 25. Conditions at Yuda dam are characterised by two faults . . . "in parallel with each other in the distance of 15 m, crossing from the upstream of the right bank towards the downstream side of the left side bank. Between them the rocks are shattered considerably." Model tests were made with and without the fault being reproduced on the model near the dam bottom. It was found that the fault has a limited effect on stresses in the dam at the base only.

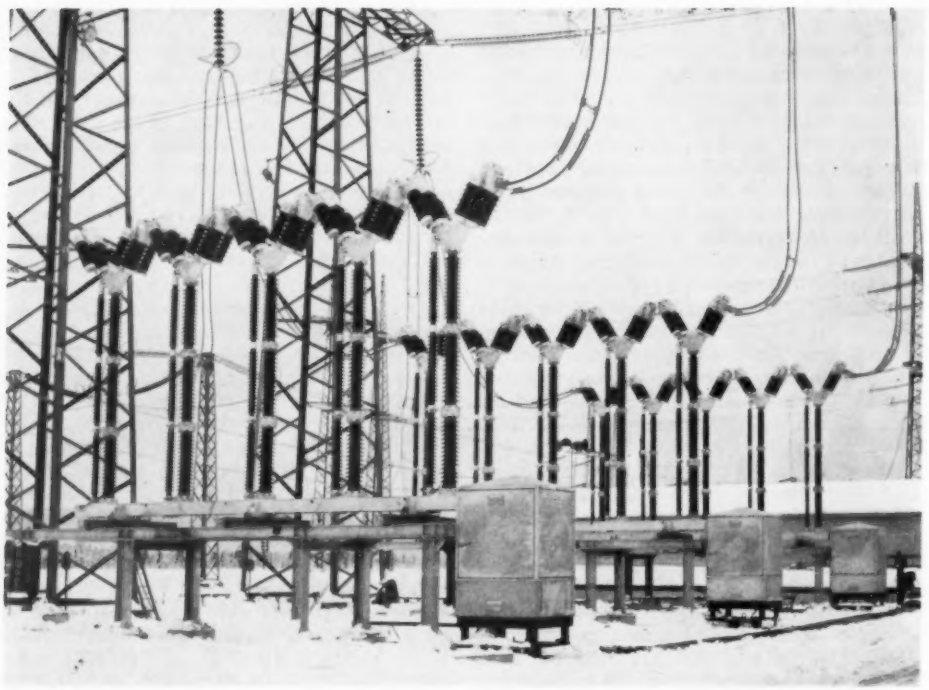
The Portuguese arch gravity dam of Bemposta and the buttress dam of Miranda are described in C.12 and C.11. The "Influence of Forced Vibration on the Stress Imposed on Arch Dams" is analysed in Paper C.14 by Tremmel (Austria). (This is a paper that should be compared with some Japanese publications on earthquake effects on dams.)

Erosion of the Nile due to interception of silt in the High Aswan reservoir is examined in Communication C.7.

General Impressions

The Seventh Congress on Large Dams was definitely as interesting as any of its predecessors. In spite of the efforts of the Executive Committee in submitting a set of new questions to each Congress, it could be feared that repetition would progressively slacken the interest in successive meetings. This was not the case. On the contrary, it was felt at the Rome Congress that more valuable information, more basic facts and more new ideas were coming forward than at any previous Congress. Designs were submitted that are bolder than any past project. Theories and methods of calculations were developed that bring the expert designer a step forward. An entirely new chapter of paramount importance was opened with Question 25 on underground work and valuable information on this subject was made available.

Minimum-Oil Circuit Breakers for 420 kV



The accompanying illustration shows one of two three-phase banks of Series HPF500 minimum-oil circuit breakers supplied by Sprecher & Schuh Limited, Aarau, Switzerland, for service on the 380-kV system of the Swedish State Power Board. The circuit-breaker banks are rated at 420 kV.

The design is based on an axial blast rupturing chamber in which the arc is extinguished by an oil-vapour jet generated by the arc. The moving contact is advanced and retracted by means of a lever linkwork; it is provided with a removable tungsten tip and engages silver-plated contact fingers mounted on individual springs. It is stated that currents up to 27 kA can be broken without difficulty. These rupturing chambers are mounted in pairs in V-shaped formation, the operating linkwork being common to the two chambers. The number of these assemblies required per phase depends on the operating voltage, the minimum number being one—giving two breaks per phase—which is suitable for voltages up to 72·5 kV. For 420 kV five assemblies in series are employed, giving ten breaks per phase.

Each V-assembly is carried on a separate solid porcelain post insulator mounted on a horizontal steel structure containing the operating rods and the opening springs. The operating mechanism, which is mounted on one end of this chassis, is a motor-operated spring-closing mechanism which can also be hand operated in emergencies. It is suitable for rapid reclosing, having enough energy stored for a full open-close-open cycle. Connection between the chassis and the linkwork in each V-assembly is made by a rotating column of porcelain.

To ensure that the voltage is equally divided be-

TECHNICAL DATA FOR ONE MAIN BREAK

	Rated value	Values proved by tests
Rated current, A	1,250	
Rated frequency, f	50	
Normal short-circuit performances		
Single-phase rated voltage, kV	35·0	37·3
Rated breaking current, symm., kA	26·3	27·0
asymm. (50%), kA ...	32·4	37·2
Peak making current, kA ...	67	79
Rated natural frequency, kf ...	15	16–19
Amplitude factor	1·5	1·5
Rate of rise of recovery voltage, V/μs	2,220	2,540
Operating duty	o–co	o–co
Phase opposition		
Single-phase recovery voltage, kV	60·0	64·5
Breaking current, symm., kA	11·0	11·0
asymm. (50%), kA	13·5	14·2
Natural frequency, f	10	10
Amplitude factor	1·5	1·5
Rate of rise of recovery voltage, V/μs	2,550	2,940
Operating duty	o–co	o–co
Lines on no-load		
Capacitive currents ranging from, A	0–550	0–550
No restrikes for voltages below, kV	35	35·3

tween the series-connected breaks, in the open position and during interruption, the breaks are paralleled by grading capacitors and, in special cases, also by grading resistors. The resistors and auxiliary interruptors are mounted in oil-filled insulators alongside the main rupturing chambers; these contacts are actuated by the linkwork of the main V-assembly and close and open after the main circuit-breaker contacts.

Disconnection of lines on no-load without danger of a restrike is aided by a piston, actuated by a spring compressed during the closing movement, which forces fresh oil into the extinction chamber.

Exhaustive tests were carried out on this circuit breaker during development at the maker's short-circuit testing station at Aarau, at the Delle Company's station at Fontenay (Paris), and by KEMA in Holland, as well as tests in the Swiss 220-kV system and the Swedish 380-kV system. The summarised figures in the accompanying table show that in all cases the test values were equal to, or greater than, the rated values.

Although the HPF500 series is a comparatively recent development, orders aggregating well over 80 three-phase groups and ranging from 170 to 420 kV have been received from Switzerland, Germany, Austria, Spain, Norway, Sweden, and Brazil.

The Northfield F.7 Dumper

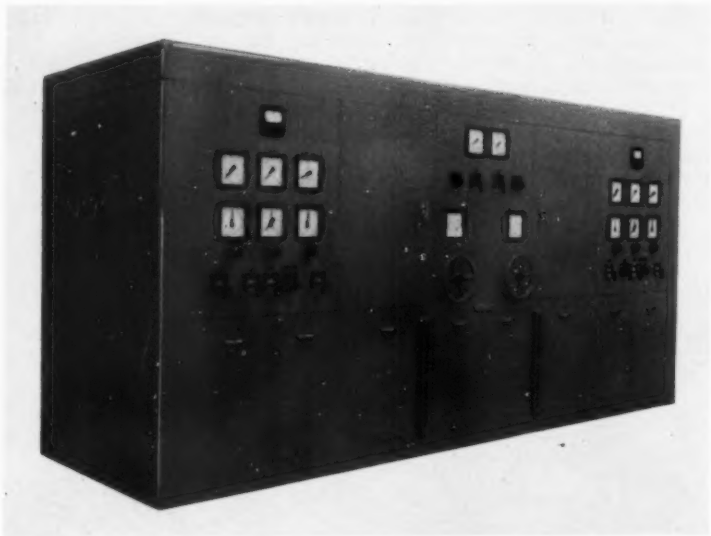
A recent newcomer to the medium-capacity range of dump trucks is the articulated Northfield F.7, which has a nominal capacity of 7½ cu yards and a 25,000 lb payload. The machine, which is manufactured by Northfield Industrial Fabrications Limited, whose selling agents are George Cohen, Sons & Co. Ltd., Wood Lane, London, W.12, is stated to have exceptional manoeurability owing to its articulated power steering, a turning circle less than the length of the machine, horizontal body pivoting and clutchless drive. The maximum speed on the level is claimed to be 28 m.p.h.

The "spotting area" of the hopper is 8 by 10 ft, and a total tip of 78° is claimed to take seven seconds, tipping being effected by double-acting hydraulic side rams. Return to the carrying position is said to take five seconds, and can be accomplished while the machine is moving.

The front and rear sections are hinged vertically, to give a steering pivot through 180°, and horizontally to allow 30° of relative movement. The final drive transmission incorporates disc-type parking brakes. The machine is said to have a low centre of gravity, which minimises the risk of turning over sideways, and as both the drive and the parking brakes operate on the front wheels, it is claimed that it is virtually impossible to tip the machine over an edge while dumping. The road wheels are interchangeable.

Power is provided by the Ford 6D engine, which develops 96 b.h.p. at 2,250 r.p.m., through a Brockhouse torque converter. The final drive unit incorporates fully floating axles and uses standard Fordson Major parts. The hydraulic pump, which is housed in the final drive unit, is driven from the power take-off of the torque converter and is live at all times.

Woodward Electro-Hydraulic Cabinet Actuator



Woodward Governor Company, Rockford, Illinois, USA, has announced the addition of an electro-hydraulic cabinet actuator to its line of mechanical - hydraulic governors. This unit is the first production governor in Woodward's manufacturing history that does not employ mechanical governing as the basic element of control. Static electrical components replace such devices as the ball head assembly and temporary-droop dashpot normally found in mechanical-hydraulic governors. Electrical circuits are said to permit greater flexibility in the arrangement of equipment for simpler and less expensive plant layout. For example, the power mechanism may be located very close to the turbine pit, controls can be mounted on the bench board on the generator floor and electrical components can be placed in almost any desired location. No specialised training for maintenance men is said to be required.

As is the case with mechanical-hydraulic actuators, the speed signal is received from a permanent-magnet generator coupled directly to the generator shaft. This signal is at a voltage that is proportional to the speed deviation, and is fed into the first stage of a two-stage balanced push-pull magnetic amplifier. The amplified deviation voltage is differentiated to provide an acceleration signal. The output of the amplifier represents the desired opening of the main relay valve. This opening is achieved through the action of an electro-hydraulic transducer, which is mounted directly on the relay valve. A typical Woodward electro-hydraulic cabinet actuator is illustrated above.

The Airvane RP-260 Compressor

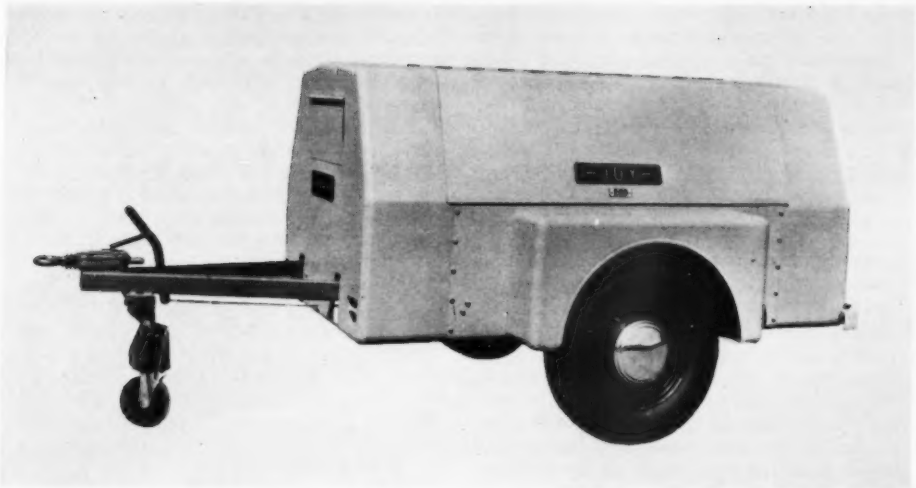
The Air Power Division of Joy-Sullivan Limited, 7 Harley Street, London, W.1, have introduced a new rotary portable compressor, known as the Airvane RP-260, and the makers claim that it has a particularly low weight and bulk in relation to output. The RP-260 is mounted on a robust two-wheel chassis fitted with a front-hinged jockey wheel, and is 7 ft 10 in long, excluding tow-bar, and has an all-up weight of 3,500 lb. Free-air delivered output is 260 ft^3/min at 100 lb/in^2 with maximum operating pressure of 120 lb/in^2. The unit is available with a choice of three diesel-engine drives; Ford and Perkins water-cooled, and Ruston air-cooled engines.

Except for the two-wheel chassis, the main departure from the earlier Airvane design is in the engine-compressor adaptor housing unit. This has been enlarged to incorporate in a single cast housing the air receiver, air-oil separator, the oil reservoir, and the main compressor-drive gear assembly. The ceiling between adaptor housing, compressor and engine is designed to ensure that no pressure is transferred against the engine-flywheel assembly. The seals used are the normal carbon-ring spring-loaded type, immersed in oil. The adaptor-receiver unit is stated to be an exclusive Joy-Sullivan feature, for which patents are pending.

A built-in electrical safety circuit is incorporated to minimise the possibility of major damage arising from operator carelessness or mechanical fault. The circuit will stop the engine immediately in the event of high engine water temperature, low engine oil pressure, or high compressor air discharge temperature.

Another feature that is said to be exclusive is the thermal by-pass oil system. Interconnecting the oil-cooler system with the direct separator-compressor oil return line is a sensitive, thermally operated by-pass valve. On starting, or under very cold conditions, the thermal valve allows warm oil from the separator to by-pass the cooler, routing it direct to the compressor. As the compressor warms up the thermal valve routes an increasing quantity of oil through the cooler, thus maintaining automatic adjustment of oil temperature under all starting and running conditions.

The rotary compressor has first and second stage cylinders arranged in a compact side-by-side unit, mounted in a single cast block. The drive between rotors is through helical gears, with the main drive from the engine through involute spline coupling. No clutch is required, as the rotors start at atmospheric pressure and progressively build to full load on ap-



proaching optimum speed. A totally closing inlet valve allows the rotors to run in vacuum when not under load.

The compressor is flood-lubricated by a positive displacement gear-type pump which feeds all moving parts. On mixing with air in the compression chambers the oil lowers the air temperature and acts as a compression seal between the sliding vanes and the cylinder walls. The oil is then carried in suspension to the two-stage filter-separator, incorporated in the adaptor-receiver unit. A series of baffles causes turbulance, which results in the removal of the major proportion of oil from the air. Any residual oil is extracted by a special Fibreglass separator element situated inside the adaptor-receiver unit.

The RP-260 is provided with the Joy patented Servair demand control by means of which the required discharge pressure is claimed to be maintained under constantly changing demand conditions by an adjustable dial, calibrated from 70 to 120 lb/in^2. Over the full range of output, the proportional capacity control is said to automatically govern engine speed to suit the demand within a 10-lb differential on the control setting.

Elapsed-Time Meter

A new elapsed-time meter for recording the time that a piece of equipment has been in use is being produced by The English Electric Co. Ltd. It is said to be applicable to any piece of equipment that is used intermittently, and on which planned maintenance or a time log is required. The meter is normally connected so that it is automatically switched on and off with the apparatus which is being metered. It can register up to 9,999·9 h in steps of 0·1 h. The cyclometer register is driven through a train of gears by a self-starting, non-reversing, synchronous motor. Operation is from a.c. supply in the voltage ranges 100–125, 200–250, and 400–440 V. The frequency can be either 50 or 60 c.p.s.

The meter is available in two case types, of which type H21M is a 4-in square, flush mounting, switchboard pattern case. The motor is mounted internally and two terminals are provided on the base plate to connect the motor to the supply. The meter has a small revolving pointer to indicate that the motor is energised. The other type, S25 or S35, is a 2½-in or 3½-in square moulded black plastic case designed primarily for panel mounting. The motor is mounted externally, and connection to the supply is made by a pair of flexible leads. It is lubricated with a special grease for operation in extreme temperatures.

Improved Case Tractor Shovel

J. I. Case Co. Ltd., of Mill Road, West Drayton, Middlesex, England, recently introduced their series D 1,000 tractor shovel. This machine has the same power (100 h.p.) and standard bucket capacity (2 cu yards) as its predecessors, but by increasing the torque-converter stall ratio from 1·72 : 1 to 1·92 : 1, the drawbar power has been increased to 28,000 lb. The lift capacity is said to have been increased from 23,700 lb to 26,750 lb, and the breakout force to have been increased to 18,300 lb.

The exterior hydraulic pipework above the bonnet has been repositioned and this is said to give greatly improved visibility. The driving controls have been rehoused in a centrally mounted turret, which has

been separated from the dash to be nearer the driving seat, and the bucket and ripper controls have been moved to under the right arm rest, all of which is calculated to improve working conditions. For easier maintenance and service, hydraulic track adjustment, a dry-type air cleaner, a new "swing-up" type front radiator grill and repositioning of interior components have also been incorporated.

Book Reviews

Reglungstechnik (Second Edition). By Prof. Dr. Ing. Georg Hutarew, Stuttgart Technische Hochschule. Springer Verlag, Reichpietscufer 20, Berlin, W35. 179 pp. 196 ff. Price, 18 DM., linen-bound 21 DM.

The Foreword to the second edition of this work indicates that some of the suggestions mentioned in WATER POWER, May 1956, and elsewhere have been adopted by Prof. Hutarew in the application of regulation theory to water-turbine governors. The original review makes it unnecessary to dwell on the contents, but comparison with the revised version is worth while.

The first three chapters are of a mathematical character, and the only change, except for minor amendments, is the introduction of locus diagrams in cylindrical co-ordinates with numerical values to illustrate the equations.

Chapter 4, dealing with speed-measuring devices, is curtailed by deleting some of the locus and inverse locus diagrams and Section 4.3, covering I-type elements, which are of limited application. Several Continental firms attach important advantages to the accelerometer pendulum, and the more-detailed approach in deriving transfer functions and frequency response is therefore useful and interesting, although the analysis is terminated without showing whether these claims are justified.

The descriptive and analytical material in Chapter 6, on typical governors, is little changed, except that the developed fourth- to seventh-order differential equations are simplified to second-order approximations by making certain time elements vanish, but futher analysis is not pursued. The extended treatment of accelerometer governors is, however, more complex. Information on the specification and determination of governor characteristics, including quality of regulation and inaccuracy, has been added with typical numerical values; this meets a criticism of the first addition, but nevertheless fully developed examples would have been welcomed.

Chapter 7, on overall turbine characteristics and regulation, now expresses speed and moment relationships in dimensionless terms, which simplifies and generalises the subsequent treatment of disturbed conditions including, inter alia, water-hammer effects to show the influence of long and short pipeline parameters on the frequency curves and their location in the phase planes.

Chapter 9, on stability investigations, is practically unaltered, save for the use of cylindrical co-ordinates.

The Conclusions emphasise that the text merely introduces regulation theory, neglecting friction, lost motion and dead time in the mechanical system, despite which the complex equations are first approximations. For precise component and overall performance the governor designer, erection or operating engineer must therefore resort to testing of pendulums, pilot-valve movements, dashpot motion, return gear and servomotors with their interrelated characteristic times. Experimental equipment has been devised, but in practice machine and network-load self-regulating characteristics intervene and demand field investigations for evaluation.

The second edition of Hutarews' "Reglungstechnik" is basically that published in 1955, with several amendments of practical importance and some in nomenclature and analytical treatment. After a lapse of six years, during which electrohydraulic governors and other developments have been introduced, it is, perhaps, disappointing to find little new information, but nevertheless this is a valuable reference book for the governor specialist.

Apparatus for Measuring Water-Turbine Governor Characteristics. By Dr. A. Schmid. Doctorial thesis presented to, and published by, Stuttgart Technical High School. 120 pp. 40 ff. Paper bound.

The review of Prof. Hatarew's "Reglungstechnik" mentions experimental equipment for determining water-turbine-governor characteristics, and stresses the need for numerical examples illustrating their importance. Dr. Schmid's thesis sponsored by Profs. Hutarew and Leonhard covers these points in a valuable introduction to regulator problems. The theme is the development of equipment for comparing governor designs and evaluating overall static and dynamic performance, from which the influence of individual components can be assessed, including intermediate effects. The thesis includes main sections:

Method of Investigation, where steady-state and transient conditions are defined diagrammatically in terms of transfer functions and frequency response.

Experimental Equipment, comprising a sine-wave generator and input- and output-signal measuring facilities from which phase angle, frequency response and transfer function can be deduced for disturbance frequencies of 0·3–9·0 c.p.s. and amplitudes up to $\pm 10\%$. The input-speed oscillations, resultant servomotor outgoing amplitudes, and displacements are expressed in non-dimensional relationships.

Frequency Response. The Voith governor tested is described by two schematics which are subsequently reduced to a block diagram from which the overall frequency response is derived from Hutarew's analysis for pendulums with adjustable oil dashpots, and servomotors with and without rigid return motion gear. This leads to a fifth order differential equation, the solutions of which, where appropriate, are divided into real and imaginary parts for presentation of 34 experimental curves plotted in complex plane coordinates showing the effects of various adjustments, damping and non-linearity.

Transfer Function. By neglecting certain time factors in the basic differential equation a first-order exponential solution for a step function is derived which generally confirms recorded speed variations and servomotor positions. A second approximation leads to difficulties, but an approach is made to it in another Stuttgart Technical High School thesis by A. Widmann (1959).

These methods of investigating the dynamics of water-turbine-governor and regulating loops deserve encouragement, and should, in due course, embrace inertia loads inherent in hydraulic and mechanical components of prototype machinery, mechanism backlash, lost motion and network characteristics. If such effects could be expressed in the elegant terms of Dr. Schmid's thesis it would be invaluable to design and operating engineers concerned with governor problems. In its present form it is an enlightening companion to Hutarew's "Reglungstechnik" for those unfamiliar with regulation-theory mathematics.

Petrographic and Engineering Properties of Loess. Engineering Monograph No. 28. By H. J. Gibbs and W. Y. Holland. Published by the US Department of the Interior, Bureau of Reclamation, and obtainable from the Office of the Assistant Commissioner and Chief Engineer, attention Code 841, Bureau of Reclamation, Building 53, Denver Federal Center, Denver 25, Colorado, USA. 37 pp., 24 ff. Price $1·00.

Loess is a wind-blown soil that covers vast areas of the central parts of several continents of the world, including the USA. Problems involving considerable consolidation under certain moisture and load combinations, poor stability, seepage and erosion frequently arise with this soil, because its natural particle structure is frequently very loose and contains appreciable voids. On the other hand, loess can often be remoulded, particularly by the action of water, into a soil with good engineering properties. This booklet describes the work carried out by the staff of the Bureau of Reclamation on this material, with particular reference to the deposits in the states of Nebraska, Kansas, Idaho and Washington.

The authors commence with a description of the soil, its probable origin and its petrography, and then proceed to a very thorough analysis of its physical properties. Much of this study is based on results obtained from the sites of the Bureau's various hydraulic structures in the Missouri River basin. The paper then describes the results of specific research studies carried out, mainly with plate-loading and pile-driving tests. The possibility of ponding loess foundations in order to develop the weakest condition prior to construction is discussed, and this method obviously has its greatest potential application in the case of hydraulic structures. This treatment was applied to the loess on which part of the Medicine Creek dam was founded, and it is shown that consolidations of up to 2 ft were recorded, most of which were induced during the construction phase.

Recommendations for driving piles in loess are made, and these are based on extensive loading tests carried out under a variety of conditions. They are followed by a discussion of the virtues of employing the density of the soil as a criterion of its potential settlement. The paper ends with the authors' conclusions on the properties and behaviour of the soil, and a useful list of references.

Stream Gauging. By M. G. Hiranandani and S. V. Chitale. Published by the Central Water and Power Research Station, Poona, India, 1960. 277 pp., 78 ff. Price Rs. 6·75.

In a country such as India, which claims to have the most extensive system of irrigation in the world, it is natural that river gauging should achieve prominence, and with the great expansion in river development of recent years, the necessity for a systematic and thorough assessment of her water resources has become imperative. The collection of river discharge data in India is not normally under unified control, and it has, therefore, become essential to standardise the procedures for stream gauging and such related work as sediment sampling.

The Director of the Central Water and Power Research Station, Shri Hiranandani, was entrusted with the task of preparing a comprehensive manual on this subject, which was to be designed to suit the conditions obtaining in India, and "Stream Gauging" is the result of this work. The authors specifically reject claims to originality in their publication, except in a few particular cases, but they have drawn upon 118 references in compiling a most comprehensive treatise on all aspects of the science (and art) of stream gauging, and thus have skimmed the cream of good practice in this field.

The book is divided into two main parts, the first dealing with water-level measurements and the second with discharge measurements. There is little upon which to comment in the body of the manual, except to say that every recognised practical method is described in detail and with simplicity, and advice is given on the appropriateness of each method. Part two concludes with a chapter on records, which very properly emphasises the need for well-kept records, and proposes standard sheets for the main observations and calculations. The four appendices contain some useful data for the practising hydrologist, including an example of the design of an aerial cableway, and standing-wave flume and fall designs. The manual concludes with a glossary of terms, conversion tables and the references.

This manual should prove of great value to those responsible for the field measurement of river flows and levels, not only in India itself but throughout the considerable portion of the world where the quantitative determination of water resources is becoming of vital importance.

Palisades Dam and Powerplant. Technical Record of Design and Construction. Published by the US Department of the Interior Bureau of Reclamation and obtainable from the Office of the Assistant Commissioner and Chief Engineer, attention Code 841, Bureau of Reclamation, Building 53, Denver Federal Center, Denver 25, Colorado, USA. 535 pp. 188 ff. Price $10·00.

Engineers sometimes lay themselves open to criticism for not publishing sufficient information on their work for the mutual interest and benefit of their fellows. Certainly many works go undescribed or are only briefly publicised. Whatever the reasons for this tendency, no criticism can be levelled at the US Bureau of Reclamation, for their excellent series of technical records, of which this publication on the Palisades project is the latest, describe in minutest detail the history of a project from its very beginnings until operation is well under way.

The Palisades project is a multipurpose development involving irrigation, power, flood control, and recreational facilities, and is located on the Snake River in eastern Idaho. The reservoir has a live storage capacity of 1,202,000 acre ft. The earthfill dam is 270 ft high above the foundation, and has a volume of 13,571,000 cu yards and a length of 2,100 ft. The power station is supplied by a 26-ft diameter concrete-

lined tunnel, terminating in four 14-ft diameter penstocks. There are four 30-MVA generating units, with Francis turbines operating at an effective head of 190 ft and a discharge of 2,140 cusecs. The project was constructed between 1951 and 1957 at an estimated total cost of nearly $62 million.

The technical record is divided into three parts. Part I deals with general planning, historical information, a description of the scheme, a summary of costs, and geology. Part II contains six chapters covering the design of the various features of the work and their components. Part III includes one chapter on contract administration, and four chapters comprising an account of construction operations and equipment installation. The record concludes with seven appendices covering detailed costs, speed and water-hammer studies for the plant, analysis of fixed-end arch sections for the spillway, and a bibliography. The table of contents is very comprehensive, and renders an index unnecessary.

This publication would be of value in any hydro-electric design office, and the various specialists will find much to interest them in individual sections of the document. The US Bureau of Reclamation are to be congratulated on their contributions to the common pool of experience, and we look forward to reading further technical records.

Introductory Soil Mechanics and Foundations. By George B. Sowers and George F. Sowers. Published by The MacMillan Company, New York, USA. 386 pp. 163 ff. Price 56s.

The first edition of this book was published some ten years ago, and the ensuing period has witnessed rapid developments in soils engineering. It is not surprising, therefore, to see that the second edition has been considerably revised. The basic arrangement of the book is largely unaltered, but great care has been taken to ensure that each section has been brought up to date or expanded where greater clarification was called for. As a result this edition is not only longer but is a considerable improvement on its predecessor.

The advance in the science of soil mechanics is demonstrated by the change in the authors' definition of a soil, which, in the first edition, is given as "any unconsolidated material that can be excavated and handled with pick and shovel," and, in the second, as "any unconsolidated material composed of discrete solid particles with gases or liquids between." This more scientific approach is evident throughout the book, and the authors have rightly placed great emphasis on the basic principles that govern soil behaviour. The importance of mineralogy, physico-chemical forces and structure, and their relation to shear strength, consolidation, compaction, and soil stabilisation are stressed.

Among the newer concepts that are dealt with are those concerned with the bearing capacity of shallow foundations and of piles, and more space is given to the rational application of the basic principles to foundation analysis and design. The shear strength of saturated cohesive soils is another subject that has benefited from the revision. Material has been added on drainage, soils classification, soil expansion, anchored bulkheads, stability, and earth-dam design.

An interesting new feature of this edition is an appendix giving unit costs in the USA in 1960 of a selection of items covering foundations, drainage, earthwork, soil stabilisation, and exploration work.

The first edition established itself among the standard introductory text books on soil mechanics, and this position should now be well consolidated by the improved second edition. From the student's point of view, the clarity of presentation will commend itself, and there is an abundant selection of problems at the end of each chapter.

Symposium on Rockfill Dams. Transactions of the American Society of Civil Engineers, Vol. 125, Part II, 1960. 800 pp. Obtainable from the Executive Secretary, ASCE, 33 West 39th Street, New York 18, New York, USA. Price $12·00.

Seventeen papers on rockfill dams were presented to the Power Division of the ASCE at their June 1958 Convention, and discussions were arranged over the next 2½ years. It was then decided that the symposium was of substantial permanent value and should be published in a single volume. This volume includes, with only two exceptions, all ASCE literature on rockfill dams for the years 1954–60. As a result, it is probably the most authoritative and up-to-date publication now available on this subject.

It is obviously not possible to judge this book as a single item of technical literature, as so many different authors are involved. It will be sufficient to say that here we have facts given and opinions expressed by most of the leading North American engineers in this field, and not a few eminent engineers from elsewhere in the world. The 75 rockfill dams mentioned either in the papers or in the discussion have been constructed in some 21 different countries, and thus a representative selection of dam types and construction techniques has been presented.

In addition to the papers dealing with specific dams, there are others devoted to more general considerations. In particular, the paper on Design and Construction Problems by Bleifuss and Hawke discusses the problems relating to rockfill dams having impervious zones of earthfill. Design theories are treated only lightly, in view of the abundant literature on this aspect, and the paper deals largely with matters of a more practical nature. Two papers on sloping-earth-core dams are given, both by Growdon, and the last paper in the symposium is in the nature of a review and statistical digest. This deals with such matters as a sound definition of a rockfill dam (suggested as a dam of which at least half the material in the maximum cross section is comprised of loose rock placed by dumping), the basic types, classification and terminology, the advantages of deck-type rockfill dams, settlement, and greater height and economy. An imposing list of structures is presented in an appendix, each dam being classified and the main slopes given.

There can be little doubt that there is no civil engineer who would not benefit to some degree from a perusal of this volume, and it can be thoroughly recommended as a modern practical reference work. The ASCE are to be congratulated on their initiative in preparing it.

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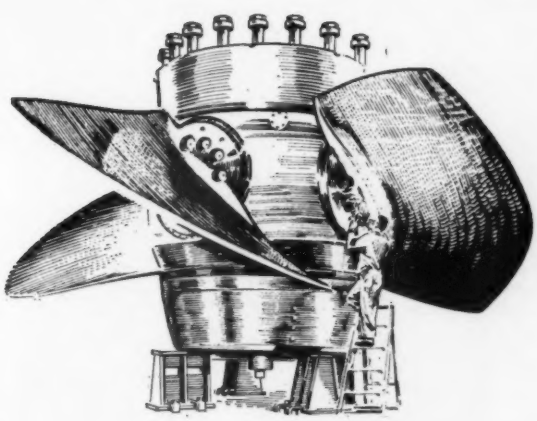

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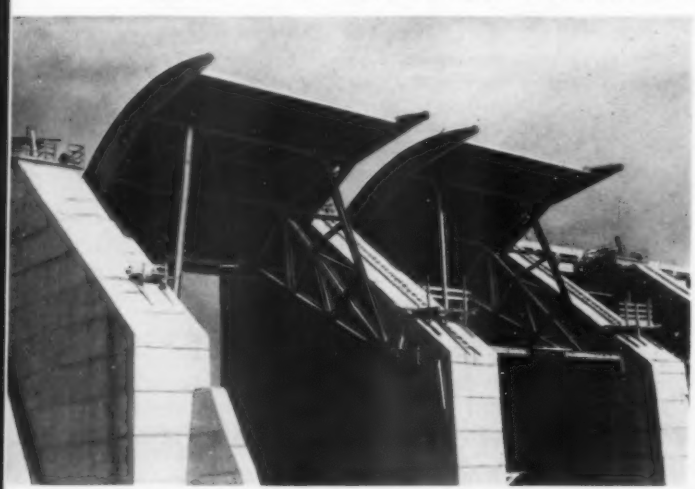
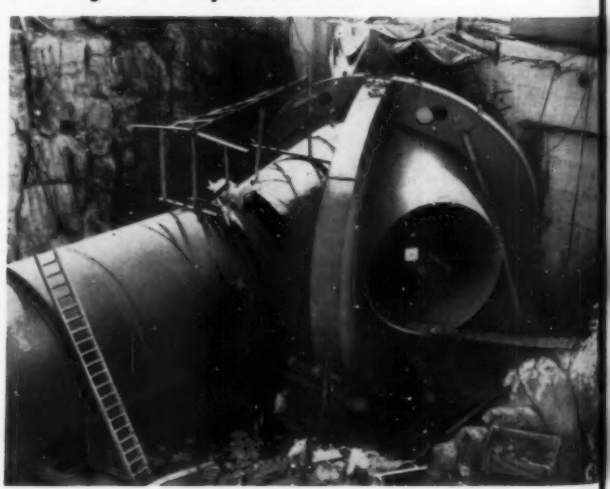




Abstracts from the World Technical Press

Short-Delay Blasting

Following an article on the application of short-delay blasting devices to quarrying (September 1960 issue of the undermentioned journal), the author has now extended his survey to civil engineering, and deals first with surface excavation. He describes the box-cut methods of blasting, and then discusses large-scale blasting in built-up areas, and the blasting of ditches in rock. The final instalment of the series is devoted to blasting in tunnelling and demolition work. In tunnelling on contract, the accent is on speed; the tendency is therefore to make the pull per round as long as possible, thus reducing to a minimum the time lost in handling drilling equipment, intervals in blasting, preparations for loading, and so on. The burn-cut, which gives a freer choice of pull, has thus become virtually standard practice in the smaller tunnels, since other methods, such as the wedge cut using angled holes, give insufficient depth of lift. Both burn or shatter cuts and wedge cuts are reviewed in their application to blasting in half-second-delay rounds. Before substituting short-delay for half-second-relay detonators, it should be realised that, despite the satisfactory pull of the round, excessive rock throw may cause damage to timbering, and create too shallow and too extended a pile of debris for efficient loading. The drilling pattern is then discussed for both wedge or vee-cut, and burn or shatter cuts. Once a satisfactory combination of delays has been achieved, consideration must be given to the delaying of the dependent holes in the enlargement of the cut area. As to excessive rock throw, experience has shown that reductions of the order of 20% in the explosive charge ratio can be made, due possibly to a greater portion of the energy from the explosive being expended in doing useful work on the rock. The paper concludes with a consideration of various ways in which blasting can be applied to demolition work. (R. F. Bennett, *Australian Civil Engineering and Construction*, Vol. 2, No. 1, October 1960, pp. 53–55, 7 ff.; No. 2, November 1960, pp. 57–61, 5 ff.)

Penstock Testing

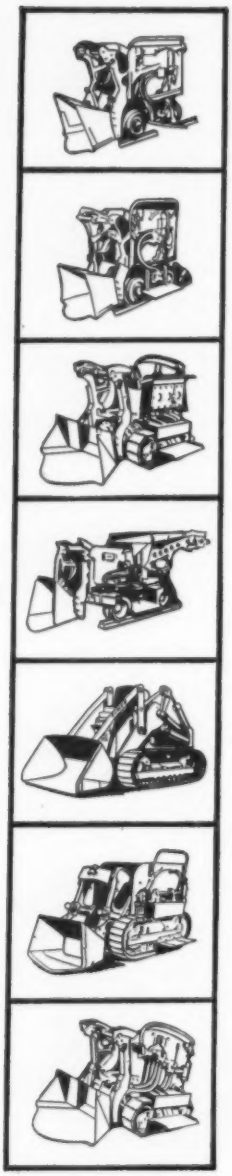
The problem under consideration in this paper is that of the resistance offered by unreinforced penstock linings to external pressures. The authors describe the extensive range of tests they carried out on concrete-embedded pipe sections 4·10 m in diameter and 2,700 mm in length. The pipes varied in wall thickness, and had shape defects; in addition, there was some clearance between pipe and lining. The paper deals first with the structure of the sections tested, the methods applied and the testing plant. Measurements were taken with the pipes in their original shape, and then stress and strain measurements were made during testing. The results are given, and their analysis brings out the special pattern to which shape defects keep, as well as their influence on the localisation of the wave of collapse and on the limit pressure; the effect of the clearances between concrete and pipe is also confirmed. These results, and their comparison with various methods of computation, lead to the conclusion that the shape-defect factor, which has been neglected in the past, should be taken into account when determining the pressure under which linings will collapse. The method of using a template to measure shape defects gives coherent results. (R. Troisvallets and R. Montel, *La Houille Blanche*, Vol. 15, No. 4, June 1960, p. 364, 28 pp., No. 5, September—October 1960, p. 551, 9 pp., 27 ff.)

The Niagara Power Block

A short account is given of a visit made by the author to the Canadian and US Niagara power stations, with special emphasis on the pumped-storage plants. The whole complex of works totals 3,952 MW in capacity, and constitutes the greatest power block set up in the western world. Even among the large developments carried out in Soviet Russia, there are only two instances of installed capacities of similar magnitude—the Kubyshev-Stalingrad block on the Volga, and the Bratsk power station on the Angara. (Professor Dr.-Ing. Otto Kirschmer, *Die Wasserwirtschaft*, Vol. 51, No. 4, April, 1961.)

Progress in Slovenia

This is a reprint, in German and Slovenian, of a lecture given by the author at the Graz (Austria) Technical University. Following introductory notes on the organisation of the electricity industry in Slovenia, and on its production and consumption, the advance of construction work on generating plants and transmission systems is reviewed. It is assessed that the utilisable resources of the Drava, Save, Soča, Mura, Kolpa and other Slovenian rivers could produce a total of 10,000 GWh a year, and the total output of economically possible hydro plants in Yugoslavia is estimated at 60,000 GWh. Slovenia's hydro-electric production in 1959 reached 1,485·9 GWh, that is to say, only about 15% of the available resources are exploited. From 1945 to 1959, the total installed capacity increased from 220 MVA to 648 MVA, the hydro-electric contribution to this increase being 417 MVA. Projects now under consideration are briefly reviewed. Owing to deforestation in the Soča region, this river has now taken on a truly torrential character; the large volume of water that is now wasted is to be collected in storage reservoirs to be provided on the upper Soča and its tributary Idrijca. On the upper Drava, the last link of the Dravograd-Maribor chain of pier-type power stations is now in course of construction. The Fala plant, erected in 1918 and subsequently enlarged in 1926 and 1931 to an output of 36 MW, is being supplied with an additional 18-MW generating set, so as to adapt its discharge capacity to that of the other stages of the system. A third set is also being added to the plant at Mariborski. In addition to power generation, the plants on the Lower Drava, i.e., the Maribor-Ormož reach, are to serve other purposes, particularly water supply and irrigation. All these plants, Loka, Hajdoše, Borl and Ormož are of the conventional run-of-river type. The use of low-head tubular turbines is contemplated for the installations of the Sava River system. When the Austro-Yugoslav agreement was signed in 1954, another bilateral agreement came into force for the exchange of energy



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and machinery between the two countries. Austrian electrical equipment is bartered for Yugoslav current, and the Austrian surplus of summer energy is exchanged for Yugoslav winter energy generated in the Dinaric-Adriatic region. At the end of his paper, the author draws attention to the undeveloped 30-km long stretch of the Mura, another section of the Austro-Yugoslav border the hydro-electric development of which would prove highly beneficial to both countries. (Ing. Vekoslab Korošec, *Elektrotehniški Vestnik*, Vol. XXVIII, No. 6–7, 1960, p. 121, 8 pp., 15 ff. German text, pp. a13 to a16.)

Determining Backwater Curves in Channels

The only tables available for making computations on backwater curves are those applying to channels with a downward slope. In this study, the author shows that the tabulation of Bakhmeteff's function can also be utilised for determining profiles in channels with an upward sloping bed. (Ferruccio Alacevich, *L'Energia Elettrica*, Vol. XXXVIII, No. 3, March 1961, pp. 205–207.)

Ardon Power Station

A short description is given of this installation, which is situated near the village of the same name in the Rhône valley, and which utilises the waters of the Lizerne and Morge streams. The main generating equipment consists of two 27,800 h.p. twin-nozzle Pelton wheels, each with a flow of 3,000 lit/sec at a net head of 790 m, the runners being overhung on the alternator shaft. A particular feature of this plant is that although the manifold of the penstock, which is laid outside the building, is buried, it has only one anchor block upstream. On the other hand, the inlet valves and the Y-pipes can slide freely on their supports, so that the whole supply pipeline is fully independent. If the ends had been connected rigidly with the turbine frames, the elongation or contraction of the manifold, resulting from temperature variations or from the water pressure, could have produced dangerous bending stresses in the frames. To rule out these excessive stresses, a pattern of hinged fixation of the nozzles has been provided by means of two plastic rings filled with an incompressible fluid; this enables the nozzles to swivel, thus suppressing any bending stresses on the flange binding them to the frame. The turbines were supplied by the Vevey Engineering Works Limited, and the alternator by Ateliers Sécheron. *Bulletin Technique de la Suisse Romande*, Vol. 87, No. 9, May 6, 1961, p. 148, 1 f. on cover.

Lünersee Power Station

This article begins with a description of the installations of the Vorarlberger Illwerke A.G. (WATER POWER, 1959, August, p. 289; September, p. 327), in which particular stress is laid on the voltage-regulating equipment of the Lünersee plant. A detailed account is then given of the two series of tests carried out, first at the Oerlikon works, on a model of the generator and network, prior to delivery, and subsequently, at Lünersee, on the installed equipment. In view of the slightly differing characteristics of the two groups of generating sets, Nos. 1 and 2 on the one hand, Nos. 3, 4, and 5 on the other, most experiments were affected on No. 1 and No. 3 sets. The results obtained, which were found to be in close agreement on the whole, are discussed at length. Separate paragraphs are devoted to the method of determination of step response and frequency response of one regulator from the oscillograms of a regulation process, the step response of Lünersee regulating equipment, and its frequency response. The Lünersee equipment has now been in service for over two years and is still giving every satisfaction. (Th. Laible, *Bulletin Oerlikon*, English Edition, No. 339, p. 29, 28 pp., 43 ff.)

NOTE: An article on the Lünersee power station is also included in *Schweizerische Bauzeitung*, Vol. 78; No. 45, November 10, 1960, p. 278; No. 46, November 17, 1960, p. 741; 14 pp., 19 ff.)

Lower-Durance Development

The Ste. Estève-Janson power station, downstream of the station put into service on May 27, 1959, at Jouques (WATER POWER, January 1960, p. 43), constitutes the second stage of the series of five plants that is to utilise the Lower Durance between the Cadarache intake (confluence of the river with the Verdon) and the Etang de Berre, north-west of Marseilles, which the Martigues canal connects with the Mediterranean. An uncommon feature of the Ste. Estève-Janson power station and of the future Mallemort stage, projected farther downstream, is the absence of river intakes; a bypass channel will enable the turbines of both plants to be supplied without interruption, in case of a stoppage at the upstream plant. The installations, which are described in detail, include a 28·7-km supply canal, designed to cope with the operating discharge of 250 m³/sec, and also the normal surges caused by additional releases from the Cadarache compensating reservoir. A forebay supplies each of the three penstocks (5·5 m in diameter and 235 m long) of the main generating sets by means of a 6 by 4 m control gate of the fixed-roller type, and also the left-bank penstock (2·5 m in diameter and 170 m long) of the small ancillary plant. A main bypass channel on the right bank, 19 m wide and 330 m long, joins the main tailrace, and, on the left bank, a channel 3·2 m wide and 150 m long, bypasses the ancillary plant and connects with the Marseilles canal (both bypasses are equipped with stilling pools at their downstream end). The main power station, which operates at a gross head of 60 m, has three generating sets consisting of 45-MW Neyrpic Francis turbines coupled to 50-MVA Alsthom alternators, running at 187·5 r.p.m.; each 5,650-V alternator is connected to its own transformer; the control and service rooms are sited above the draft tubes. The equipment of the ancillary power house, the specific purpose of which is to utilise the additional supply of 15 m³/sec at 40-m head provided for the Marseilles canal, consists of a vertical-shaft 5,620-kW Jeumont-Riva Francis turbine operating at 333 r.p.m., and a 6,000-kVA alternator. This small plant will be controlled from the main power station, and to ensure accurate regulation of the water returned to the Marseilles canal, an emergency spillway can discharge surplus water into the main bypass. The tailrace, which has practically the same characteristics as the power canal, forms, over a length of 3,700 m, the headrace of the projected Mallemort installation. The development of the Ste. Estève-Janson project affects a dense network of road and rail communications and other

services, and involves an extensive programme of relocation. No fewer than 27 new bridges are required, with a total length of 900 m. The article includes an account of the geological investigations for the project, as well as the large-scale preliminary work necessitated by the nature of the soil, especially on the 15-km stretch of the supply canal, which runs through marly clay and sandy deposits. Work began in 1958 with the diverting of the Marseilles canal, which supplies the city with drinking water, and crosses the site of the power station. Excavation work totals 11,750,000 m^3 in volume. Work on the main installations has been in progress since July-August 1959 and, in spite of the delays caused by the bad weather during the 1959-1960 winter, it is expected that the first generating set will undergo its initial tests in July 1962. This seems feasible as the excavation output in April 1960 was 997,000 m^3, only 60% of which was loose ground. The Ste. Estève-Janson power station is designed to be operated ultimately by remote control from the future Mallemort plant. (P. Weingaertner, Ingénieur en chef EDF, *Construction*, Vol. XVI, No. 2, February 1961, 11 pp., 16 ff.)

NOTE: The editorial of our issue of January 1957 was devoted to the Durance project, which was subsequently described and discussed at length in the April–July issues of the same year, pp. 146, 177, 220 and 260.

Designing Hot-Hooped Penstocks

A new method of calculation is advocated, which applies especially to penstocks reinforced by hot-applied rings rectangular in cross section, the lower faces of which, i.e., the faces in contact with the penstock, are grooved. The problem had already been resolved in 1955 by Ing. Giovanni Mattioli, but, in the procedure now under review, coefficients in finite terms are used, and it is claimed that computation is thus made easier, and gives quicker results. The authors first examine the elastic behaviour of a hooped pipe, proceeding from the fundamental case of one circle of radial forces acting inwards around a circumference, and from the assumption of a perfectly elastic pipe of infinite length. They then consider the cases of one and two indefinite series of circles of forces, and discuss the elementary stresses occurring in pipes reinforced by this type of hooping. Three practical examples of application are given. (Paolo Aguzzi and Enos Maccari, *L'Energia Elettrica*, Vol. XXXVIII, No. 2, February 1961, p. 142, 16 pp., 13 ff.)

Automatic Mountain-Stream Intakes

A full description is given in French of this improved pattern of stream intakes, of which a number have been erected in connection with the Roselend development (WATER POWER, February 1961, p. 49; previous references: January 1955, p. 39, and July 1956, p. 282). Standardisation, which has reached a fairly wide extent in the case of dimensions, is now fully achieved in respect of the mechanical equipment, which remains identical for intake discharge capacities up to 5 m^3/sec. Other advantages include flushing at exactly the right moment and repeated as many times as is strictly required, thus reducing water losses to a minimum, no supervision required beyond periodical maintenance visits, and no electric power required. It should be understood, however, that these intakes have been designed to be installed at altitudes where vegetation is virtually non-existent, so that there is no debris problem. (Louis Pousse and Jacques Mollent, EDF, *Schweizerische Bauzeitung*, Vol. 79, No. 16, April 20, 1961, pp. 259–261, 7 ff.)

New Concrete Plant

A short description is given of the German ELBA batching "star," an improved system of weigh-batching plant, which eliminates the lifting of large quantities of aggregates into heavy and expensive steel silos high above the ground. The aggregates are brought to site by tipping trucks and dumped into radially arranged compartments at ground level in the centre of which a scraper plant is installed. The Elba scrapers, which are either manually or automatically controlled, move the material from the outer areas to the self-emptying area, or discharge zone, located at the centre of the star, where it is weighed and then discharged from the weighing bin into the skip hoist, which lifts it into the concrete mixers. Economy of operation is an important feature, and smaller plants with a weighing-bin load capacity of 71 ft^3 and corresponding scraping equipment can be operated by two men to produce up to 60 cu yards per hour of mixed concrete. For concrete plants with particularly high outputs, radial scraper stars can be equipped with a preset pneumatically operated control mechanism with controls placed at any convenient point on the site. (*Australian Civil Engineering and Construction*, Vol. 2, No. 6, March 3, 1961, p. 61–62, 2 ff.)

Shear Stresses in Hollow Gravity Dams

A practical and fairly rapid method of computing shear stresses in the elements of hollow gravity dams is described. This method applies especially to those dams with walls that are either vertical or slightly taper upwards, and the stresses computed are those resulting from the weight of the dam and water pressure. (Angelo Testa and Silvio Spagnoletti, *L'Energia Elettrica*, Vol. XXXVIII, No. 3, March 1961, p. 197, 8 pp., 7 ff., 5 tables.)

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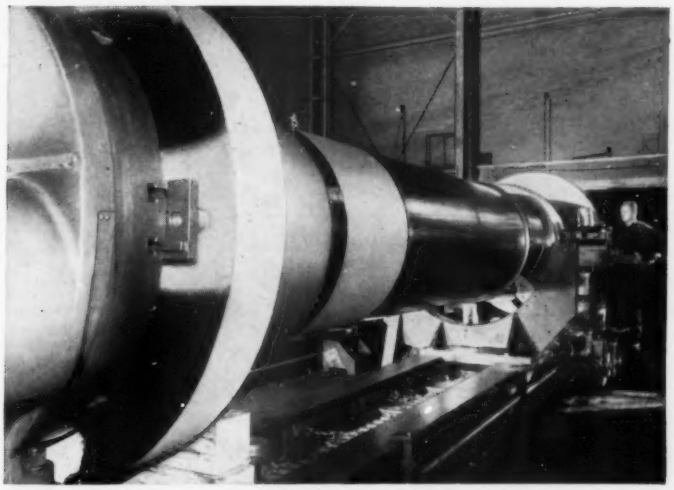

Ten Kaplan type turbines, each expected to produce 157,000 horsepower under 87 feet head, are now being completed by Dominion Engineering for the Wanapum Project on the Columbia River for Grant County Public Utility District No. 2, in the State of Washington. The pictures at the right show a turbine shaft being machined and a runner blade being pre-welded with stainless steel at Dominion Engineering where complete engineering design and hydraulic model testing were carried out. At the left, a pit liner is shop-assembled with a stay ring shipped to Willamette Iron and Steel Company, Portland, Oregon, sub-contractor for plate steel, and other parts.

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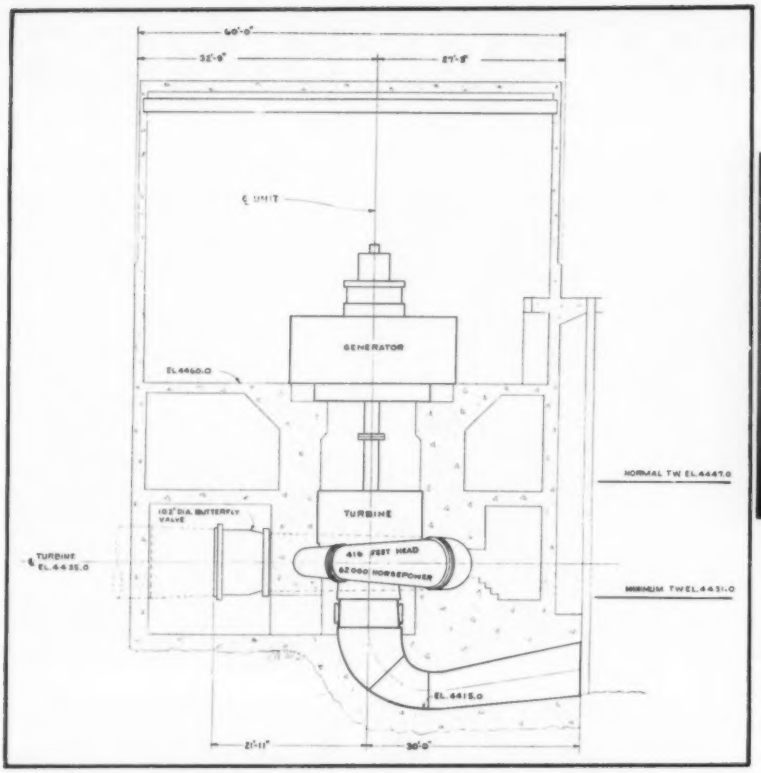

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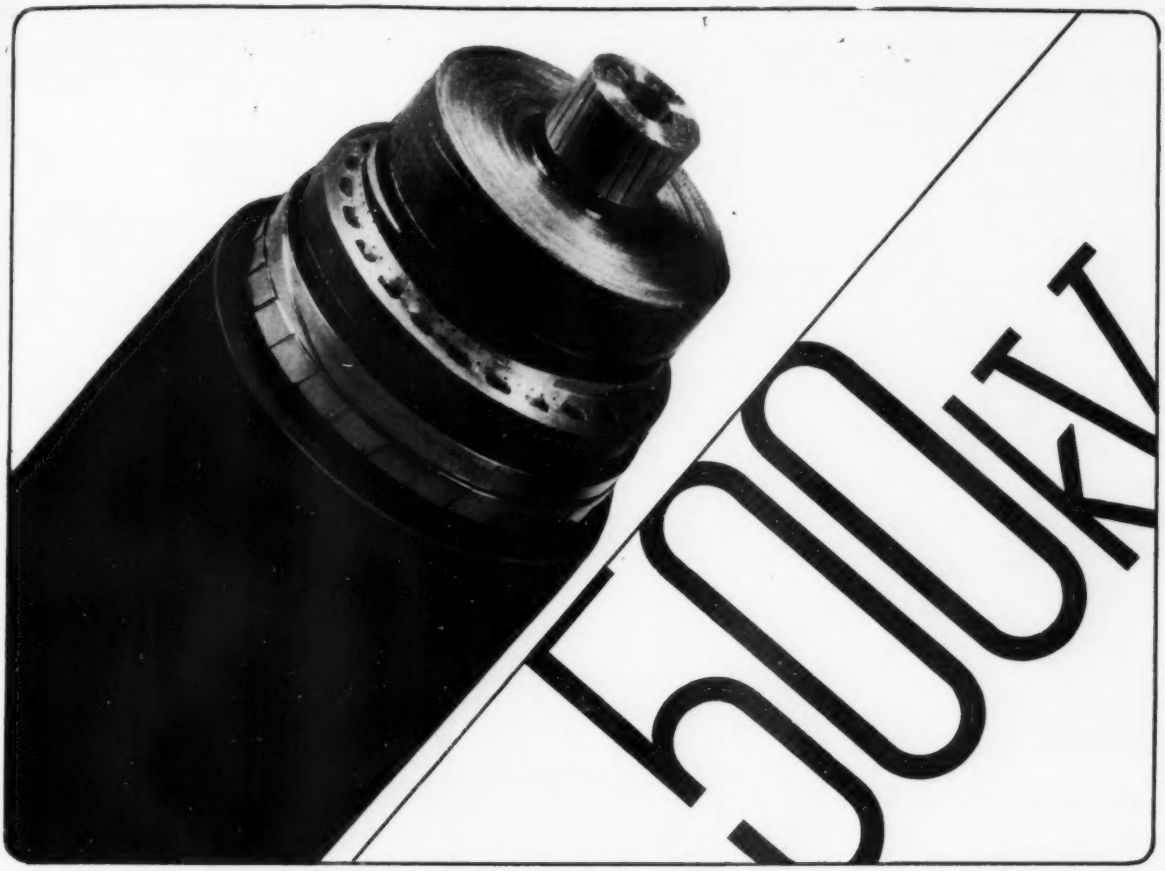

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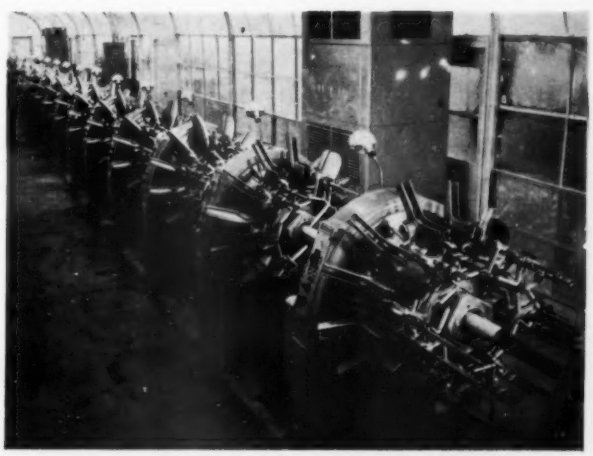

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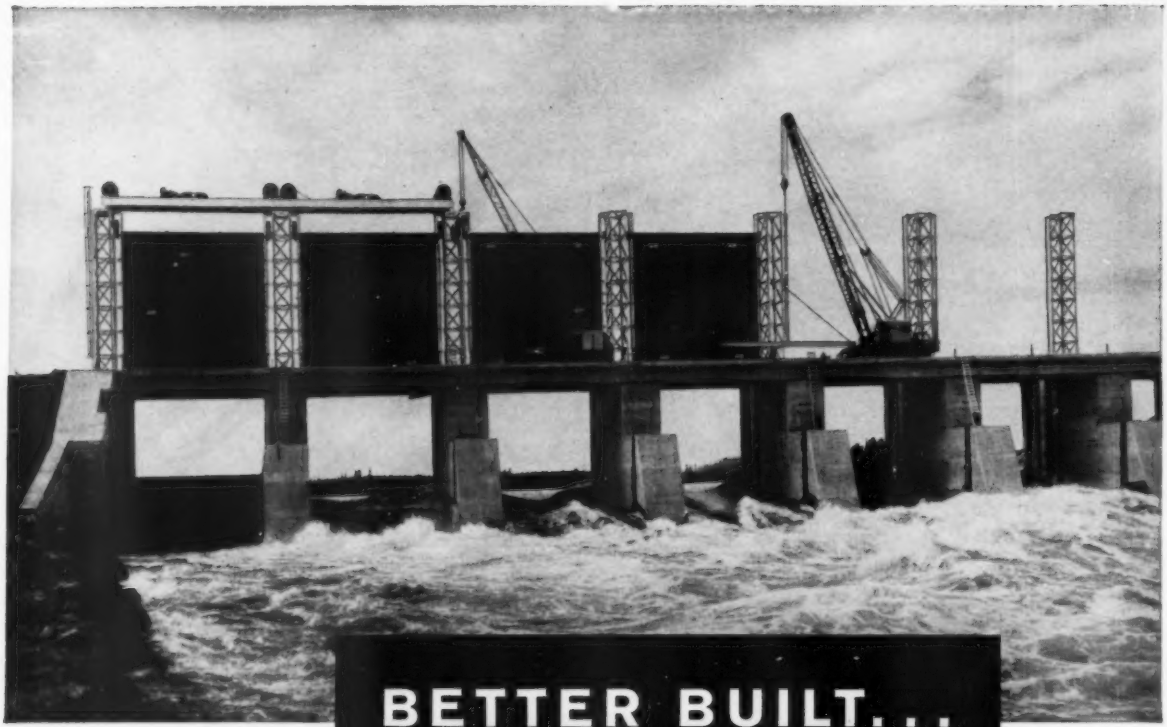

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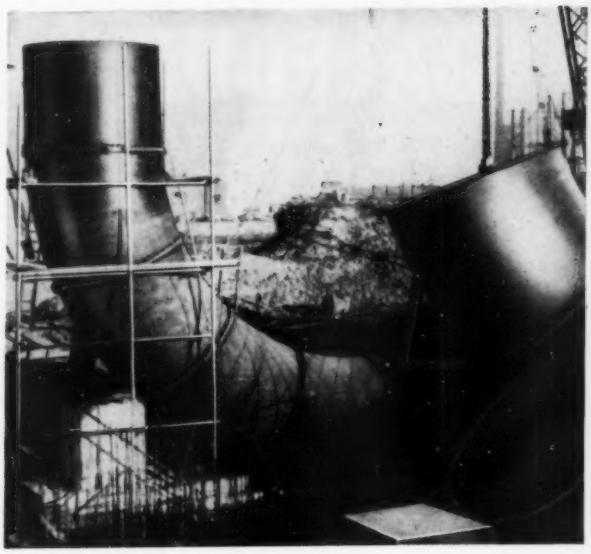

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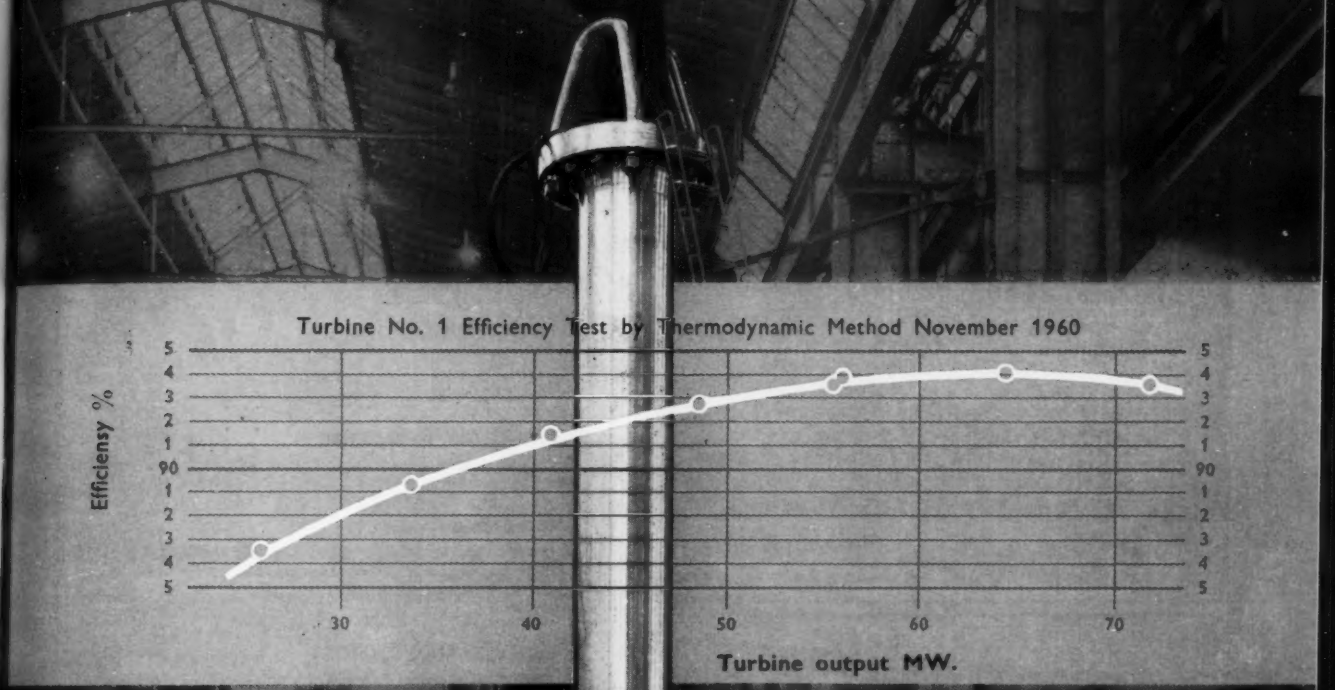

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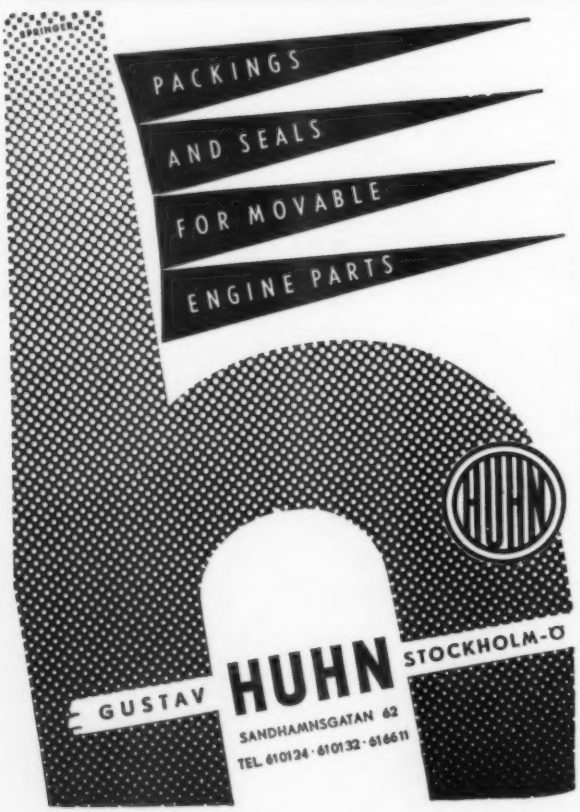

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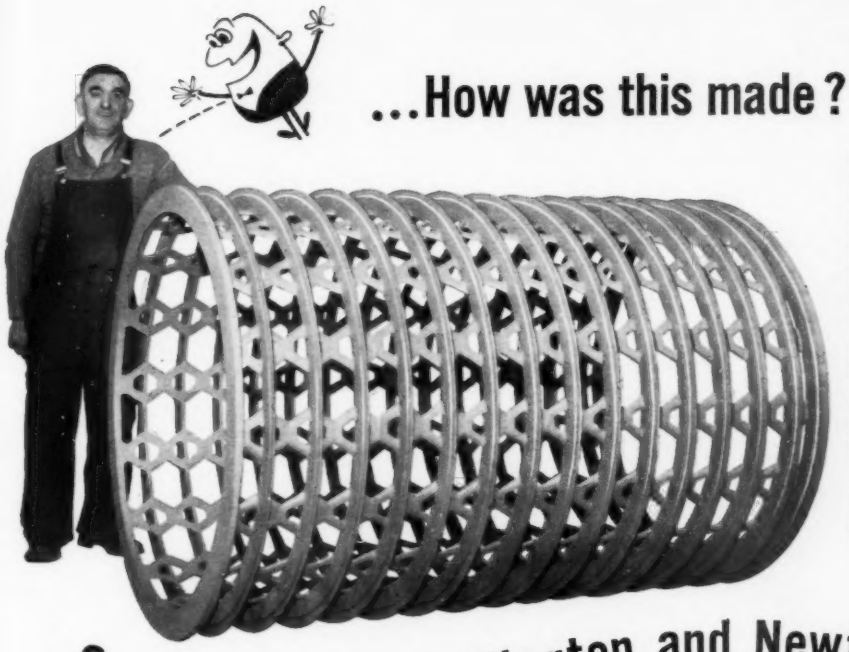

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